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WATER QUALITY MEASUREMENT AND INSTRUMENTATION. PROCEEDINGS OF A SYMPOSIUM HELD AT CINCINNATI, OHIO ON 29-31 AUGUST 1960

Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio

1961

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WATER QUALITY MEASUREMENT AND INSTRUMENTATION

Proceedings of the 1960 Seminar
at Cincinnati, Ohio

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WATER QUALITY MEASUREMENT AND INSTRUMENTATION

Proceedings of a Symposium held at
Cincinnati, Ohio, August 29-31, 1960

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Public Health Service
Bureau of State Services
Division of Water Supply & Pollution Control

Robert A. Taft Sanitary Engineering Center
Cincinnati 26, Ohio

1961

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The Robert A. Taft Sanitary Engineering Center is a national laboratory of the Public Health Service for research, training, and technical consultation in problems of water and waste treatment, milk and food safety, air pollution control, and radiological health. Its technical reports and papers are available without charge to professional users in government, education, and industry. Lists of publications in selected fields may be obtained on request to the Director, Robert A. Taft Sanitary Engineering Center, Public Health Service, Cincinnati 26, Ohio.

FOREWORD

Recent studies of present and anticipated future requirements for water quality data have emphasized the need for methods which will assure an adequate flow of this vital information. We must have these facts to develop and put into effect sound water quality management policies and programs.

Thus the Symposium on Water Quality Measurement and Instrumentation has focused attention on an important problem in the water pollution control programs of the Nation. Intensified efforts by industry and governmental agencies will be needed to apply to this effort technological experience already at hand in other fields. Available instrumentation must be adjusted to the demands of more or less continuous monitoring of stream quality. We need devices which will detect, measure, and record continuously at least the more important of those water quality constituents that can now be determined only at the laboratory bench.

It is hoped that the papers and discussions included herein will serve both as a base and guide for future efforts in this field. Estimating the benefits of the extensive exchange of information amongst the 330 Symposium registrants, who represented a wide variety of professional disciplines from both government and industry, is, of course, difficult. It seems assured, however, that the Symposium will have a profound effect on future activity along these lines.

Responsibility for the organization and over-all direction of the Symposium was ably carried out by Mr. Ralph C. Palange, Deputy Chief of the Basic Data Branch. The assistance provided by the local arrangements committee at the Sanitary Engineering Center was essential to the successful conclusion of the Symposium.

These Proceedings were prepared through the services of the Robert A. Taft Sanitary Engineering Center. Mr. Leo Weaver, Chief, and Mr. Stephen Megregian, In Charge, Laboratory Activities, both of the Water Quality Section, Basic Data Branch, edited the manuscript for publication. The various papers are presented as submitted by the authors and do not necessarily reflect policies of the Public Health Service. It was necessary to delete some of the informality of the recorded discussions, but every effort has been made to retain the expressed and implied intent of the discussants.

Richard S. Green
Chief, Basic Data Branch
Division of
Water Supply and Pollution Control

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WATER QUALITY MEASUREMENT AND INSTRUMENTATION

WELCOME*

by JOSEPH E. FLANAGAN, Jr., Assistant Director
Robert A. Taft Sanitary Engineering Center

It is a pleasure, once again, on behalf of the Director and the staff of the Sanitary Engineering Center as well as on behalf of the Division of Water Supply and Pollution Control, to welcome this large group to Cincinnati for this symposium on Water Quality Measurement and Instrumentation.

Over the last six years, these symposia covering a wide range of technical interests in the environmental health fields have been effective and productive forums for the participants and have been a source of valuable publications useful to the fields at large. The opportunities to meet old friends and colleagues as well as new acquaintances, to exchange technical information, and to discuss problems have equalled if not surpassed the value of hearing the formal papers of the meetings themselves.

It may be interesting to know who is here for these sessions. A quick analysis of the organizational affiliations and professional disciplines of the 250 pre-registrants revealed the following interesting facts.

People are here from 34 States and the District of Columbia. Most of these are representing official State agencies concerned with water quality. These include those from water pollution control boards, limnologists, fishery biologists, fish and conservation commissions, and State health departments.

There are representatives of 18 universities, including faculty from the departments of zoology, public health, civil and sanitary engineering, biology, and bacteriology, as well as several students from the University of Pittsburgh.

Interstate representatives include 3 interstate agencies, the N. Y.-N. J.-Conn. Interstate Sanitation commission, INCODEL - Interstate Commission on the Delaware River Basin and ORSANCO - Ohio River Valley Water Sanitation Commission.

The Federal Agencies are represented by some two dozen from the PHS, 15 or 20 from USGS, and at least one representative each from Corps of Engineers, TVA, Bureau of Reclamation, U. S. Army and U. S. Air Force.

There are representatives from 42 industries present. These include makers of instruments as well as industries concerned with water quality per se. Other organizations which are represented include: American Association of Railroads, Stanford and Mellon Research Institutes, Lakeshore Laboratories, and the AWWA.

Journals represented include Control Engineering, Water and Sewage Works, and Water Works Engineering.

In addition, we have a chemist from the Institute of Environmental Sanitation of Taiwan, a consultant biologist from Kingston, Ontario, a gentleman from Ghana, and the Chief Medical Officer of the Metropolitan Water, Sewage and Drainage Board of Sydney, Australia.

I hope you will excuse my failure to introduce each of this last group individually because this review is based only on preregistration and there may be other distinguished guests who registered today who would be overlooked on the basis of information available to me at this time.

The seminars sponsored by the Sanitary Engineering Center are considered to be an important part of our job. This one is no exception. The consideration of water quality measurement and instrumentation is basic to eventual successful water quality management of which you will hear more later.

In spite of all the work done in the past, the development of analytical methods and of accurate, dependable and economic instruments of detection in the field of water in many respects lags behind similar work in the fields of industrial hygiene and air pollution. A similar symposium on air instrumentation was held in Ann Arbor a number of years ago and a manual of air instrumentation resulted through close collaboration of official agencies, individual scientists and manufacturing companies. Very recently, the American Conference of Governmental Industrial Hygienists has published a large volume, updating the earlier effort and making available to its members and others an excellent illustrated compendium with operating and structural data on several hundred devices used by practitioners of air sanitation.

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* Mr. Flanagan was introduced by Mr. Palange, General Chairman of the Symposium.

It would be my hope that your deliberations today, tomorrow and Wednesday may eventually be as fruitful as those of our colleagues. We are not starting any too soon.

I have great confidence that you will have a most successful meeting. The fact that you are here attests to your interest and that of your agencies and companies. It also attests to your knowledge and skill. No one here will be as handicapped as the caterpillar who saw a butterfly go by overhead and said to his fellow caterpillar, "Believe me, Jack, no one will ever get me up in one of those things"!

Our problems here will not be solved automatically because of inherited characteristics.

In closing, I hope all of you will be able to visit the Center on Wednesday afternoon. You also should know you are welcome to come and see us at any time in the future.

Thank you very much.

SYMPOSIUM OBJECTIVES

GORDON E. McCALLUM,
Chief, Div. of Water Supply and Pollution Control
Public Health Service

I am pleased to have this opportunity of discussing briefly with you the objectives of this Symposium. First, however, I want to add my own welcome to that just extended by Mr. Flanagan. It is indeed a pleasure to see all of you here for these sessions.

It is significant that this composite group--people from industry, instrument makers, public officials, engineers, scientists, chemists, biologists and others--is uniting its various interests toward a common goal.

Has it occurred to you that as we open this first Symposium on Water Quality Measurement and Instrumentation, we set the stage for a new milestone in the field of water pollution? It seems fitting that we hold such an important meeting in Cincinnati. It was here at the original Stream Investigations Station that such men as Streeter, Phelps and others made earlier history in their classical works on stream purification phenomena, of which the Public Health Service has always been very proud.

Our earlier colleagues were dealing with organic pollution not unlike the type that streams receive in their natural state. Its source was known and the stream, with its natural flora and fauna, was acclimated to the assimilation of those wastes.

Today the streams are being invaded by many new and unfamiliar types of wastes to which we might apply the term "persistent," as does the military in describing such deadly manmade air pollutants as nitrogen mustard gas.

These newer wastes, together with residual materials remaining after treatment of conventional wastes, are raising questions as to just what is happening to the quality of the Nation's waters. These questions are coming from water works operators, agriculturists, recreational groups, conservationists and public officials.

The growing importance of water supplies to meet municipal, industrial and agricultural demands, makes it necessary that we know and are able to predict the quality of water much more precisely than we do today.

The wastes escaping treatment, both older types of organic pollution and the new 'persistents' of the chemical age, are certain to increase in volume, strength and complexity as populations and industry grow.

To meet the need for basic information on the national water pollution situation, the Federal Water Pollution Control Act (Public Law 660) authorized the Surgeon General to ". . . in cooperation with other Federal, State, and local agencies having related responsibilities, collect and disseminate basic data on chemical, physical, and biological water quality and other information . . ." This provision implemented, in part, the first major recommendation of the Presidential Advisory Committee on Water Resources Policy which was "That the present program of basic data collection be accelerated, and be programmed and carried out on a more consistent and definite basis." This Committee pointed out that the current program for measurement and study of chemical and biological water quality was particularly deficient.

The rapidly expanding need for water emphasizes the urgent necessity to manage its quality as the demand approaches the final limit of supply. The fact that we have entered the era of water reuse poses the problem: How do we manage it? By what criteria? With what tools? Not only must we use effectively the measurement tools we now have; we must develop new and more efficient armament as needs arise.

The need for automation and instrumentation to provide continuous long-term water quality trends in monitoring our water resources is growing. Automation will be expensive but is the only means by which we can fully arm ourselves with the data necessary to conserve available water supplies to meet the increasing demands.

Automation and instrumentation for the measurement of water quality is, as this group well recognizes, a relatively unexplored field. Much of what will be said here in the next three days, therefore, will be exploratory and, hopefully, will open new horizons for all. It should be both challenging and stimulating.

The Symposium brings together the data collectors and users, and the instrument makers and users. We want the users to tell us what their data needs are; we want the instrument makers to tell us what is now on hand and what may reasonably become available in the foreseeable future. The instrumentation sessions will cover automation for the entire data gathering operation, including collection and analysis of the sample, transmission of the data, and final handling at the point of use.

We hope there will be a free exchange of ideas, both through the formal sessions and through your own informal discussions. It is only through such exchange that all of us can gain a mutual understanding and respect for the other's problems. It is hoped also that the instrument maker will be stimulated into development of the equipment needed by the administrative agencies for carrying out their responsibilities. From these sessions should evolve a clear definition of our needs in terms of operations, procedures, and other armament required for the proper management of the quality of our water resources.

The day is coming when we will have to manage water quality and quantity of whole river basins much in the same push-button manner that we now transmit and manage electrical power. Streams will be fully instrumented. Data will be telemetered. A central computer will turn out the finished data. We will push a button and release stored clean water or regulate pollution discharges.

In summary, then, we sincerely hope that the Symposium will:

(1) Define the role of water quality measurement in water resources management;

(2) Review in broad terms the methodology, collection, and utilization of water quality data;

(3) Evaluate available instrumentation and highlight developmental needs; and

(4) Outline methods for transmission, evaluation, storage, and other factors concerned with data handling and utilization.

The fine attendance here is one indication, among many others, that the leaders in all responsible fields are ready to meet the challenge. The kind of program you have here indicates that the necessary new approaches are recognized and will be fulfilled.

ROLE OF WATER QUALITY DATA

Chairman: MARK D. HOLLIS
Assistant Surgeon General and Chief Engineer
Public Health Service

WATER QUALITY MANAGEMENT OF THE FUTURE

By
H. G. HANSON, Director
Robert A. Taft Sanitary Engineering Center

It was kind of your program arrangers to assign a subject which allows some considerable freedom to range if not to speculate too freely. Water quality management in its broader sense is perhaps most appropriately discussed in terms of the future. At present it is more of a concept than a practice. The development of it as a practice is a major need and a major challenge of the next decade.

As I view it, water quality management of surface waters -- and I will limit considerations here to surface waters -- is a system for providing the right water quality at the right place. It embodies a set of procedures for keeping each segment of the surface water resource in the continuous dynamic balance necessary to meet the requirements of each significant use. The concept may be considered quite simple, but the development of it in a form practical for application is not simple.

The critical importance of water quality management stems, of course, from the well known expanding demand for water against an essentially fixed supply. Only one fourth of the average annual runoff or about 314 billion gallons per day is considered to be available at this time as dependable surface supply.(1) The remaining three-fourths of runoff is the familiar "wrong in time or place" portion.

Depending on who is gazing into the crystal ball, this 314 BGD of water appears to be more or less inadequate to meet future demands. If the hydrologists who estimate that about half of total runoff can be captured; ultimately are correct, then we can look forward to a surface supply from this source of about 635 BGD. Augmentation of this supply is possible in a number of way: (1) through intelligent development of the great underground water reservoirs, (2) through desalination of ocean and brackish waters, (3) through reduction of evaporation, (4) and through weather modification. There are so many imponderables associated with these possibilities that predictions of their contribution to dependable supply is almost impossible. We can assume that these will provide some supplementation of the normal surface supply, but that the amount and broad geographic availability will not be such as to alter the national surface supply picture in major fashion.

Projections of water use over the next decade or two seem to be generally accepted -- the figure of 600 BGD for 1980, for example. Less reliable are the projections for the ensuing two decades and such estimates as 1000 BGD by the year 2000 may be considered "best guesses".

As pointed out by the Senate Select Committee on Natural Water Resources(2), "it would appear on the surface that by the year 2000, total water use could exceed the limits of the Nation's developable fresh water supply resources". Counter to this view, they say, "this would not, in fact, be the case, however, because all of the various demands for water cannot simply be added together . . . . " The Committee Report goes on to point out that "water is used many times over" . . . . and that "the total of various purposes which can be served by a given quantity of water will vary from river basin to river basin . . . ."

The report makes the point I wish to emphasize, "Water is used many times over". It will be necessary increasingly to re-use water, and the extent and type of re-use will vary from place to place and time to time. Whether the re-use be two, four or six times, water quality management will be the key to meeting supply needs through water re-use. And the scientific basis of water quality management is ability to measure substances in water and understand their behavior in water.

I would like to turn now to some of the considerations of importance in water quality management of surface streams. From upland source to the ocean the stream is subject to both a series of withdrawals for use, and contributions from tributaries (and underground supplies). Because some withdrawals involve consumption loss, the stream flow is

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reduced. Other withdrawals are essentially completely returned, some slightly impaired in quality, some highly impaired and many in between these extremes. Many uses and values of the stream do not involve withdrawal at all -- the fish and wildlife, recreational and aesthetic uses and values are in the stream itself. Parenthetically, these uses and values are not inconsequential. The views of Irving Fox in "Water - Supply, Demand and the Law"(3), are of interest here with respect to what he "considers to be the most arresting feature of the water supply-demand outlook, both East and West. It is the rapid increase in water use for recreation purposes and a growing recognition of the importance of preserving the aesthetic characteristics of the Nation's water resources. Since World War II, while the national economy has been growing at a rate of about 4 per cent a year, recreation use of water areas has been increasing at a much faster pace. For example, during this period use of T.V.A. reservoirs increased at a rate of 15 per cent per year, while use of the reservoirs of the Corps of Engineers increased at a rate of 28 per cent per year. All signs now point to a tremendous increase in recreation water use during the next two decades. Since we now have about 20 million fishermen and approximately five million outboard motors, there can be no doubt about the economic importance of water-based recreation activity.

"But of even more significance than the economic activity which stems from recreation is the importance of outdoor play and relaxation to our highly urban and industrialized society. Yet the demand for clean waters is not related entirely to recreation. As forests and fields give way to factories, houses, and highways, and as areas become more densely populated, it is increasingly important for lakes and streams to be aesthetically pleasing. As our society becomes more prosperous, as well as more densely populated, I anticipate a wide-spread insistent demand that the intrinsic beauty of the Nation's water resources be maintained".

The point of view expressed by Fox serves to illustrate the wide range of quality control which we may be called upon to provide in the future. To date we have been more concerned with abating the more serious pollution conditions than with preserving clean waters. In the future it will be important to give more balanced attention to the total job of keeping water clean. The old adage of "an ounce of prevention . . . . " warrants serious attention. It should be more efficient and economical to plan water use to prevent impairment of the resource than to let use proceed unplanned and then correct the impairment.

Assuming that planned water use will be the order of things in the future, what do we need to know to control quality? First, of course, we must be able to measure qualitatively and quantitatively. Analytical methodology is the first requisite to quality management. This symposium will reflect the present state of the art and science of water quality measurement. It will show, I venture to say, that our present techniques are inadequate for the present problem. It will demonstrate, I believe, a need for methods and devices at least an order of magnitude better for problems of the next decade. As the number of substances in water increases it will be necessary to be more discriminating in what we measure. Each existing and proposed new parameter should be critically evaluated so that the corresponding measurements will be most meaningful.

A more complete understanding of the physical, chemical and biological forces in the aquatic environment -- and the interplay within and between these forces is fundamental to effective water quality management.

Physical factors have not received appropriate attention from water quality scientists. As points of discharge and withdrawal move closer and closer together dispersion, turbulence, stratification, wind action and related factors will need more precise delineation, from the standpoint of understanding, predicting and monitoring what takes place, and for the design of outfall and intake structures.

Certainly hydrodynamics will need to receive more attention in the future. Sedimentation and transport of silts and other suspended matter have received much study and have been taken into account in the design of drainage, treatment and river structures. In spite of this, control of silts and debris has not been all that it might be. Most of us have seen the streams of silt that come from construction sites, mining and agricultural operations, the debris from timbering and related activities, and certain industrial operations. More ingenuity than we have applied in the past will be required for reduction of these impacts. On the credit side of the ledger the progress made by the soil conservationists is especially worthy of commendation.

Temperature will be more significant in the future. Power growth predictions alone point in the direction of more problems resulting from thermal pollution. It will be a task of water quality management to develop the knowledge necessary to predict whether a given rise in temperature will promote or retard stream purification processes for wastes of varying character; what the effects on fish and related aquatic life will be; what the effect on growth of slimes and weeds will be. More reliable methods of forecasting the rate of heat loss under varying meteorological and hydrologic conditions are needed.

More complicated than the physical factors, are the chemical and biological ones. We live in a chemical age, and its almost endless permutations and combinations are reflected in the water environment. Separation and identification techniques and instrumentation are in only the primary stage. Our understanding of the reaction kinetics of organic chemicals in dilute aqueous solution is meager. Biochemical phenomena are reasonably understood only for the more sewage-like substances. The longer term physiological effects of newer chemicals on man are hardly understood at all; the shorter term effects on aquatic life are almost as poorly understood -- but we can assay lethality grossly. Here the need is obviously for more sensitive, quicker and less costly physiological assessment methods, for both human and aquatic life.

Our understanding of biological operations in the water environment is mostly qualitative. It needs to move in the direction of quantitative understanding -- if biological factors are to be incorporated in the system analysis matrix that will characterize tomorrow's water quality management.

A third major element of significance in water quality management is water cleaning technology. This includes the characterization of wastes, their treatment, and the monitoring of effluents. Determination of the pollutional characteristics of wastes involves procedures for measuring their amenability to aerobic and anaerobic treatment, their fate in streams, their effect on the streams and stream life, their effect on and removal by water treatment processes and their effect on humans, plants and animals. Suggested schemes for characterization of wastes have been in the literature for several years, but their general acceptance and use has lagged.

Likewise, the development of new treatment methods has lagged. Our water treatment methods totally are inadequate for the more complete cleaning of waters likely to be required in the next 10 or 20 years. The most difficult problem appears to center around the removal of ions and molecules, particularly those of synthetic organic chemicals. This is an area of research demanding much more attention than it is receiving now. Such research is a prerequisite to the successful reclamation and re-use of water that will be necessary in the future.

Up to now we have depended on using the treatment capacity of receiving waters in greater or lesser degrees. It is probable that we cannot depend on using much of the stream's assimilative capacity for the treatment of municipal and industrial wastes. Increasingly this assimilative capacity will be required to accommodate that pollution from land use which is beyond practical control: pesticide, and other commercial poison residues, natural and applied soil nutrients, eroded materials, and return irrigation contributions. Even with the most complete treatment of municipal and industrial wastes, we may be fortunate if any assimilative capacity is available as a safety factor. The significance of more advanced methods of waste treatment thus looms larger and larger. Better measurement tools to monitor residuals reaching our water courses will be more important as water quality balances become more delicate.

In order to "transistorize" the maze of scientific knowledge we hope to acquire, into its applied form -- wisdom -- we need first to reduce the many scientific languages of the physical, chemical and biological water worlds to a common one. Mathematics seems best suited to the purpose.

The first step then is to express physical and biological knowledge in appropriate mathematical terms. This is, of course, not always easy to do in precise terms, especially for biological events. The limitations of mathematical expressions of biochemical oxygen demand and oxygen sag are familiar examples of the difficulty. The next step is to develop a mathematical matrix or mathematical model into which multiple variables can be fitted. Finally systems analysis techniques are applied to solve problems presented to the system. The whole process is one of accounting. It may be likened to a system of dynamic accounting where deposits, withdrawals, fluctuating values of assets, varying rates of interest, simple and compound, are expressed continuously in terms of running balances and other management expressions essential to assessing and guiding an enterprise. It is somewhat in this fashion that I visualize the art and practice of water quality management emerging.

The resources behind the scene will be scientific staff, laboratories, instrumentation, basic data, measurement techniques, computer technology, theoretical and applied mathematics. On the stage will be all of the competing and conflicting economic, political, social, legal, administrative and technical actors. In the audience are the critics, professional and lay, the jury, the public -- striving to make sense out of the chaos; trying to separate fact from emotion; trying to separate basic issues from selfish interest; trying to identify the principles which can serve as firm foundation for law and practice.

The future significance of water quality is perhaps too obvious to belabor. We need it in developed form now, in several areas of the country. As the quantity squeeze becomes tighter and allocation doctrine and law are re-shaped, re-use will increase and water quality control will assume greater - if not critical - importance.

The potential for development of water quality management practice is hinted in the extensive treatise on "Technology in American Water Development" published for Resources of the Future. With reference to conservation and quality control the authors say "Water quality control has not received the comprehensive attention technically possible. No administrative machinery has been in motion which examines all aspects of water quality on a basin wide scale, and applies measures of quality control, including paired use plans, on a unified basis to the watershed".

This commentary has all the aspects of an invitation for some one to fill the vacuum. As we look at reasons why no one has moved more aggressively to fill the vacuum, we can see some of the same elements that may be responsible for unsuccessful efforts to develop national water policy. Beyond the lack of scientific knowledge there are so many interests, aspects and agencies involved that no one feels confident enough to take the lead or move alone.

We see constant reference to the inseparability of water management from soil and forest management. Yet something must come first, and there must be some place we can start on this most complex problem of developing the practice of water quality management. If we believe that good water is essential to national survival, that it is a "priceless" commodity, that it is the most critical factor affecting our economic development, then perhaps we should approach policy and practice development, with the view that water quality objectives should be established first, and that water and land use be adjusted to these objectives.

In this case, as in many others, we will probably have to learn to walk before we run. The local setting offers a good place to begin. Starting with smaller and simpler river basin systems, we can inventory existing hydrologic, use and quality factors and attempt to set these in a framework or system for analysis. We can then challenge the system with hypothetical -- or predictable -- conditions of supply, demand, use, and re-use and attempt to determine quality at points of significance in this dynamic system. As we acquire experience with simpler systems, and identify and formulate the more critical factors, we can move to more complex ones until ultimately we develop a methodology sophisticated enough to accommodate the kinds of water quality management problems we expect to encounter in the future. This is a technical challenge of high order and one to which all of us must respond.

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REQUIREMENTS FOR CRITERIA OF WATER QUALITY

JACK E. McKEE
Professor of Engineering in Environmental Health
California Institute of Technology, Pasadena

It is the intent of this paper to review and analyze the application and use of water-quality standards, objectives, criteria, and classifications. The paper deals also with the specific beneficial uses of water and describes some of the pitfalls in trying to establish rigid standards for the protection of these uses. Finally, it points out some of the requirements or needs in arriving at proper criteria of water quality.

No attempt has been made herein to propose specific numerical criteria for any potential pollutant or for any beneficial use; nor to consider legislative or administrative matters in relation to water quality control. Although interesting and important, such matters are beyond the scope of the philosophical approach adopted for this paper.

TERMINOLOGY.

At the outset of this discussion it is well to define several terms that appear frequently in this paper and will undoubtedly be used by subsequent speakers. First, distinctions should be made among the words "standard", "objective", and "criterion".

The term "standard" applies to any definite rule, principle, or measure established by authority. The fact that it has been established by authority makes a standard somewhat rigid, official, or quasi-legal; but this fact does not necessarily mean that the standard is fair, equitable, or based on sound scientific knowledge, for it may have been established somewhat arbitrarily on the basis of inadequate technical data tempered by a cautious factor of safety. Where health is involved and where scientific data are sparse, such arbitrary standards may be justified, on an interim basis.

A prime example of a standard that was set somewhat arbitrarily is the limit of 0.05 mg/1 of hexavalent chromium in the USPHS Drinking Water Standards of 1946. The previous limit, in the 1942 standards, had been 0.00; but one of the members of the committee making the 1946 revisions operated a water system in which some of the wells had 0.02 or 0.03 mg/1 of hexavalent chromium. He could not use these wells with the 1942 standards. To get his wells back in service, he prevailed upon the rest of the committee to raise the standard to 0.05 mg/1 — just high enough for his wells to qualify. Little or no scientific information was available to suggest a proper threshold value, but in the interests of safety the committee wanted to keep the standard as strict as possible.

Another example, based on ignorance coupled with caution, is the arbitrary limit for coliforms in saline bathing waters, as promulgated and rigidly enforced by many state health departments. Epidemiological evidence is much too sparse — indeed virtually non-existent — to justify these standards on a scientific basis; yet they provide a strong administrative crutch to bureaus of sanitary engineering that want to promote a high degree of sewage treatment, regardless of its economic justification.

The word "objective" represents an aim or a goal toward which to strive and it may designate an ideal condition. Most certainly, however, it does not imply strict adherence nor rigid enforcement by an agency or health department. It is gaining favor among engineers on boards and commissions that strive to achieve water-pollution control by persuasive methods and cooperative action. An example would be the objectives for various reaches of the Ohio River, as promulgated by the Ohio River Valley Water Sanitation Commission.

A "criterion" designates a means by which anything is tried in forming a correct judgment respecting it. Unlike a standard, it carries no connotation of authority other than that of fairness and equity; nor does it imply an ideal condition. When scientific data are being accumulated to serve as yardsticks of water quality, without regard for legal authority, the term "criterion" is most applicable. As such, it is used extensively in this paper.

To be useful, a criterion should be capable of quantitative evaluation by acceptable analytical procedures. Numerical limits are less subject to legal interpretation or administrative decisions that are vague descriptive qualitative terms. A criterion should also be subject to definitive resolution, i.e. unaffected insofar as possible by synergism, antagonism, and other complicating factors. There is a tendency, which should be avoided assiduously, to let criteria become rigid and perhaps ripen into standards. For this reason, every criterion should be regarded as flexible information, to be kept constantly under surveillance.

Definitions are also in order for the terms "potential pollutant" and "corollary pollutant". Any substance that may be present in water, whether dissolved, colloidal, or suspended, is a "potential" pollutant — potential in the sense that if concentrated sufficiently it can adversely and unreasonably affect such waters for one or more beneficial uses; and yet, if diluted adequately, it will be harmless or perhaps even beneficial. A good example is the fluoride ion.

The term "corollary pollutant" relates to a substance or living organism of natural origin that is not normally deleterious, obnoxious, or adverse to the beneficial uses of the water, but may become so when altered or stimulated by the introduction of sewage or industrial wastes. The discharge of ammonium phosphate, for example, may not in itself cause any direct pollution or toxic action; but it may stimulate heavy algal blooms with concomitant fish kills. Another good example is the stimulation of Sphoerotilis by concentrations of sugars that are not in themselves deleterious.

In water-quality discussions, frequent reference is made to the "beneficial uses of water". What are the beneficial uses and how should they be regarded or ranked?

It is generally recognized that the major uses of water embrace the following list:

1. Domestic water supply
2. Industrial water supply (including cooling water)
3. Agricultural water supply (irrigation)
4. Stock and wildlife watering (including refuge for water fowl)
5. Propagation of fish and other aquatic or marine life (including shellfish culture)
6. Swimming, bathing, and water-contact sports.
7. Recreational and commercial boating.
8. Esthetic enjoyment.
9. Water power and navigation.
10. Disposal of waste waters.

It should be recognized that these uses are not listed in the order of economic importance nor in the order of increasing or decreasing water quality. That they are uses, no one can deny; but there are conservationists who maintain that disposal of waste water is not a "beneficial" use. The author contends, however, that any use is beneficial if it has over-all economic advantages.

It is a prime requirement of any criterion of water quality that it relate to the protection of one of the beneficial uses. The accumulation of unrelated analyses just for the sake of data gathering is a waste of time and money. Monitoring agencies must constantly review their sampling and analyses to be certain that the proper data are being obtained and that they are meaningful. This message is a major one for this conference.

TYPES OF STANDARDS FOR WATER POLLUTION CONTROL.

There are two basic types of standards that have been used for control of water pollution. One type dealing with the quality of the receiving water, whether stream, lake, river, estuary, open ocean, or ground water, is commonly designated as "stream standards". The other type, referring to the quality of the wastes to be discharged from a given plant, is called "effluent standards". Each type has its advantages and disadvantages, each type has its advocates and opponents, and each type is in common use today.

Stream standards may be divided into two distinct categories (a) dilution requirements and (b) standards of receiving-water quality. Largely outmoded now, dilution requirements were favored at the turn of the century as handy yardsticks and rules-of-thumb. They were proposed first in 1887 for the Chicago drainage canal, when Rudolph Hering recommended a dilution rate of 3.3 cfs per 1,000 persons sewered. Later Hazen, Goodnough, Stearns, and others in New England proposed requirements varying from 2 to 10 cfs per 1,000 persons, depending on the characteristics of the receiving waters.

Standards of quality of the receiving water are based on threshold and limiting values for specific substances in the water, and they depend on the beneficial uses to which the water may be put. Widely used now and favored by those who feel that some sort of formalized criteria are necessary, stream standards are frequently correlated with a rigid system of stream classification or zoning whereby separate standards are set for each stream or zone. The principal advantage of standards of stream quality over effluent standards lies in the fact that they take into account dilution and the assimilative capacity of the receiving water and consequently they lead generally to an economy of treatment works for pollution abatement. On the other hand, such standards are more complex to formulate and define, and more difficult to administer than effluent standards. Where stream classification is mandatory and complicated, the program may become extremely cumbersome.

The second general type, effluent standards, may also be divided into two broad categories; those that restrict the strength and/or amount of substance that can be discharged, and those that specify the degree of treatment or percentage removal of a specific pollutant that must be accomplished by treatment or by changes in industrial processes.

Pennsylvania has pioneered in effluent standards that specify the amount of pollutant that may be discharged by special industries and each process within such industries. This program is based on a percentage removal of pollutants from "normal" for each process, as established by representatives of industry. Consequently the effluent requirements favor good housekeeping and penalize the inefficient operator.

Effluent standards have the advantages of simplicity and ease of administration, for they are well-defined and equitable among communities and industries. Their primary disadvantage lies in their uneconomical use in some cases of the assimilative powers of receiving waters.

STANDARDS VS CASE-BY-CASE ANALYSIS.

Water-quality standards for streams or effluents provide the regulatory agencies with definite yardsticks established or authorized by legislation, thereby facilitating greatly the problem of administering a pollution-control program. On the other hand, this ease of administration may result in arbitrary decisions and possible inequities to municipalities and industries. These inequities arise from the fact that many variables other than the strength and volume of the substance in question influence the effect of pollution on the beneficial uses of water. Among these variables are included the effects of pH, temperature, synergism, dilution, mixing, tidal action, chemical and biochemical changes, and hydrographic features, to mention only a few. The combination and interplay of these many factors are extremely complex and they exert such an influence on each pollution problem that the broad-brush application of statewide standards for streams or effluents may prove to be inadvisable.

In contrast, it is possible to establish an equitable and economic balance among the many beneficial uses of water, including waste disposal, by application of the principle of case-by-case determination as to whether or not a condition of pollution exists or threatens.

This principle provides that each pollution problem be analyzed individually to determine its effect upon present and future beneficial uses of the water.

Of necessity, the case-by-case stipulation precludes a broad-brush treatment on a statewide or even regional basis, and it rules out rigid stream standards and the arbitrary zoning of streams or underground basins. In effect, it depends on astute judgment by members of the water-pollution-control boards and such judgment must be founded on the most recent, complete, and reliable compendium of data pertaining to the limiting and threshold concentration of each potential polluting substance, for each possible beneficial use of the water.

Such a tome was prepared at Caltech for the California State Water Pollution Control Board in 1952, with an addendum in 1954. The demand for this volume was so heavy that a second printing was ordered in 1957. It has gained worldwide acceptance and it was translated and published in Japanese. The second printing is exhausted, but rather than reprint again, the California WPC Board in collaboration with the USPHS preferred to revise and modernize the text. A project is now underway at Caltech to prepare a second edition which should be ready in 1962. This volume (considerably larger than the first edition, for data are accumulating rapidly) will be a collation and evaluation of all readily available data for each potential and corollary pollutant, as it relates to each beneficial use.

HIATUSES.

In spite of the rapid accumulation of data relating to water quality, the collection and collation of available information will reveal that there are many gaps in our knowledge of this vast subject. Among the missing information, the following examples are prominent:

1. Effects of synergism and antagonism among potential pollutants.

2. Rates of decomposition of unstable pollutants under various conditions.

3. The relationships of water-quality criteria to the phenomena of diffusion, dispersion, and transport of wastes, such as longitudinal and transverse mixing in streams.

4. Threshold concentrations for the thousands of exotic new organic chemicals that are being conceived by manufacturing chemists, used by industry, and discharged to receiving waters.

5. Radioactivity from waste waters and from fallout, as it affects beneficial uses.

6. Subtle long-range effects, especially on biological systems and human physiology.

7. Limitations of the available water quality data, based on inadequacies of sampling and questionable analytical procedures.

8. Daily, hourly, and even instantaneous variations in the concentration of specific substances, which might be revealed by continuous sampling and recording apparatus.

Many of the foregoing gaps in our knowledge depend upon the development and utilization of proper instrumentation. It is hoped that this symposium will go far toward stimulating the use of modern instruments for the accumulation of meaningful water quality data.

SUMMARY.

Criteria are the parameters by which the quality of water should be evaluated in forming a correct judgment respecting it. Such parameters should be capable of definitive resolution and subject to quantitative analysis by acceptable procedures. Most important, they should relate to each potential pollutant that may affect adversely one or more of the recognized beneficial uses of water.

Owing to the great number of potential pollutants and their separate effects on each beneficial use, water pollution control authorities need a compendium in which all available research data relating to water quality criteria are collected, collated, and evaluated. Such a volume must be kept current, for research data related to water quality accumulate steadily and rapidly.

In applying water quality criteria to specific situations, water pollution control authorities should be cognizant of the limitations of the data. Unfortunately, criteria tend to ripen into standards that become more rigid, fixed, and accepted with the passage of time.

It is a prime requirement of any criterion of water quality that it relate to the protection of one of the beneficial uses of water. The accumulation of unrelated analyses, just for the sake of data gathering, is a waste of time and money. Monitoring agencies must constantly review their sampling and analyses to be certain that the proper data are being obtained and that they are meaningful.

EVALUATION OF WATER QUALITY PROTECTION TECHNIQUES

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My assignment is to evaluate water quality protection techniques, a formidable task. It requires us to consider the effectiveness of sanitary engineering developments of the last half century and examine sanitary engineering as it is practiced and taught today. This is a large assignment, even in brief.

Actually, the Sanitary Engineering Center should be in a good position to make such an evaluation. We receive requests for technical assistance from all parts of the Nation. Sometimes we can provide the assistance required, but often we cannot. We do not always have the funds and personnel to do the work, but more frequently we just do not have the necessary know-how ourselves. We may thus be considered to be experts in what we should know but do not. I propose to draw fully on this knowledge, or the lack of it, in this evaluation.

What do we consider to be the essential phases of water quality protection? Obviously, they should include more than the treatment of waste and water. In this analysis I shall begin at the point of waste origin and terminate at the point of water use. I propose to discuss in logical fashion the following steps in water quality protection:

1. Accounting for all pollution reaching a body of water.

2. Predicting the pollutional effects of a given waste.

3. Treating waste to prevent pollution.

4. Using the stream effectively and economically in waste disposal.

5. Monitoring the receiving stream intelligently.

6. Treating contaminated water for reuse effectively and economically.

If our mastery of these techniques is complete, we should have no great concern about protecting the quality of the water resource. If not, we should in all common sense determine where our weaknesses lie, and undertake the necessary research to correct them. I shall consider each technique separately.

DO WE ACCOUNT FOR ALL POLLUTION REACHING STREAMS?

When we think of pollution, we normally consider sewage and industrial wastes. This is not surprising. One expects an industrial plant to produce an industrial waste just as a community produces sewage. In recent years we have had to consider the growing pollutional effect of land drainage, particularly that from agricultural lands. More recently we have become aware of pollution resulting from chemical poisons deliberately applied to the water course to kill weeds, insect larvae, fish, and other forms of aquatic life. Even more recently our attention has been directed to motorboat exhaust emissions as a potential troublemaker.

It is pertinent to ask whether our common sampling and analytical procedures permit us to identify and trace the significant components of these wastes. I should like therefore to consider separately each of the avenues through which man-made pollution may reach streams.

1. Sewage is assuming new, important characteristics. For example, organic chemicals of industrial origin are often undetected and unsuspected components of sewage. It is probable that the presence of alkyl benzene sulfonate, the basic ingredient of household synthetic detergent, would be unsuspected if it were not associated with foam. One could speculate on the presence of other substances, equally resistant to treatment and equally persistent in the stream, which give no physical or chemical clues to their identity. Giving point to such speculation is the growing trend toward combined treatment of sewage and industrial waste. It is likely that in the future the waste effluent of each community will be unique because of the industrial substances it contains.

2. It is not necessary to belabor the point that the "traditional" industrial wastes, the dinosaurs of our experience, are still major problems. However, new and perhaps even more troublesome wastes are being encountered. Increasing interest is directed to radioactive wastes from uranium ore refining plants and nuclear power reactors, thermal pollution from power plants and industrial cooling operations, and the vast complex of waste substances discharged by the chemical industries. Synthetic organics are a particular problem because of the very rapid growth of the petrochemical industries. Many of these organic compounds resist destruction by the communities of microorganisms on which we depend for organic waste stabilization in the treatment plant and in the stream. They may persist almost indefinitely in the stream, and reach locations of water use many miles below the point of waste discharge. An interesting example is a benzene derivative we followed 1000 miles down the Mississippi River. This we found almost by accident. The gap in knowledge of the quantity and character of many industrial wastes is a problem of fundamental importance in the protection of water quality.

3. The increasing use of agricultural poisons, particularly insecticides, is reflected in the appearance of these chemicals in bodies of water receiving farmland drainage. DDT has frequently been recovered from streams, and even from treated water supplies. One of the new chlorinated hydrocarbon insecticides is the most toxic material yet encountered for fish. It has been used in Pennsylvania to destroy rodents in orchards. Like other such substances, it is persistent in water solution and is not easily removed by conventional water treatment processes. Here is a problem to tax those responsible for water quality management: How shall we account for a waste whose source is general land drainage rather than the point source represented by a specific outfall sewer?

4. The growing use of synthetic organic poisons to destroy nuisance water vegetation, mosquito larvae, and undesirable fish has introduced new water quality control problems. Dickinson, North Dakota, provided us with a typical case. To destroy worthless coarse fish prior to restocking with game fish, it was proposed that a fish poison be applied to the municipal raw water impoundment in use. As one would expect, the health authorities were concerned with the ability of the water treatment plant to prevent this material from reaching the treated water. With the increasing recreational appeal of stored waters, it is clear that problems of this kind will be experienced widely and frequently. Obviously, control can be applied only if it is known that the toxic material has been applied to the water source.

5. It is too early to present a clear picture of the potential problem that could result from the emissions of outboard motors. It is possible, however, that we will have in the water environment an analogy to the problem of automobile exhaust emissions to the atmosphere.

HAVING A NEW WASTE IN HAND, CAN WE PREDICT ITS POTENTIAL POLLUTIONAL EFFECTS?

Can we confidently predict the effect of the waste on the dissolved oxygen of the stream, its toxic effect on fish and other aquatic life, its tainting effect on fish flesh, its possible damage to water treatment processes, its effect on water palatability, and its

harmful effect on persons who drink that water?

I think you will agree that few agencies are presently equipped to do more than estimate the waste's probable effect on the dissolved oxygen of the stream, and to determine, within rough limits, its toxic effect on fish in the receiving water.

Several years ago the Center undertook to evaluate its ability to make such predictions. We selected a group of six organic cyanides as the wastes of challenge. Chemists, engineers, biologists, and toxicologists were assigned to determine the pollutional character of these compounds. They were instructed to exercise ingenuity wherever standard methods and equipment could not be used. Improvisation was necessary. For example, it was found that conventional organic analysis could not detect nor measure the low concentrations of compounds found to be significant. Quantitative analysis based on fish bioassay solved this particular problem.

Our experience suggests that a well equipped and well staffed laboratory can obtain the information needed to predict a new waste's probable impact on certain important downstream water uses. However, the acid test will come when we match our laboratory results against field findings in an actual problem situation. This we have not yet done.

The laboratory tests constitute an expensive, time-consuming project -- not one to be undertaken as a routine task. The toxicological phase of the study is perhaps its most perplexing aspect. The specialized services and cost necessary for determining the effect of repeated exposure to low concentrations of the waste for long periods of time would inevitably place this job out of reach of most public agencies. Equally discouraging is the probability that the toxicological study may take as long as two years.

ASSUMING WE CAN DETERMINE TOLERANCE LEVELS FOR THIS WASTE, CAN WE REALLY TREAT IT EFFECTIVELY?

Many yardsticks of waste strength and character are in use; Biochemical Oxygen Demand (BOD) is unquestionably the most common. With the best reatment processes available, a BOD reduction of approximately 95% may be obtained. A reduction in BOD does not mean that the objectionable mineral salts -- nitrates and phosphates -- have been removed. Just the opposite effect is produced in sewage stabilization by secondary treatment. Likewise, the soluble inorganic constituents of wastes are not removed by conventional secondary waste treatment processes. And it has already been noted that many persistent organics discharged in sewage and in chemical industry wastes do not have a BOD. They are either nonoxidizable or they exert their oxygen demand so slowly as to be considered nonoxidizable. Obviously, a reduction in a waste's BOD gives no assurance that such compounds have been removed or destroyed.

We have found that the effluents of biological treatment plants may contain approximately 100 ppm of volatile solids. We may equate these solids to biologically resistant organic substances in solution. We have only a vague idea as to their composition. However, this we can be sure of: we should rather not have them in our drinking water.

The possibility that so-called complete treatment of wastes may not always be sufficient was pointed out by G. E. McCallum, Chief, Division of Water Supply and Pollution Control, Public Health Service, at the 1959 Purdue Industrial Wastes Conference. A new interest has been stimulated in the future's need for tertiary treatment processes and, beyond that, for advanced cleansing of wastes. In passing I should like to say that we look to the field of physical chemistry for important contributions to such research.

IN DISPOSAL OF WASTE EFFLUENTS, DO WE MAKE EFFECTIVE USE OF THE RECEIVING WATER?

One of the great intellectual satisfactions of the sanitary engineer is the application of the oxygen sag formulation. This application assumes a rapid, efficient mixing of waste and water. Does this really occur? Streaks of waste may often be traced many miles along a water course. Obviously, the full dilution effect is not being used. This often poses stream sampling problems because of variation in waste concentration in a cross-section of a stream. It also raises pertinent questions regarding the adequacy of outfall design techniques.

Many of you have personal knowledge of the relatively poor state of the art of waste disposal into tidal waters. A profound question is, "What is the fate of a particle of waste discharged into a mass of tidal water?". Every one of the 24 coastal and Gulf States is seeking, or will inevitably seek, effective techniques to answer this question. The use of models to supplement field studies is a recent interesting development.

HAVING DISPOSED OF THE WASTE EFFLUENT, CAN WE MONITOR EFFECTIVELY THE QUALITY OF WATERS WHICH HAVE RECEIVED IT?

Until recently, few programs of water quality intelligence would present a realistic picture of changing quality conditions in a stream, and those were usually developed at great expense in special problem situations. You may recall that in December 1955 the unsatisfactory condition regarding knowledge of the quality of water impelled the President's Advisory Committee on Water Resources to recommend that improvement in basic data was urgent. This recommendation sparked the development of the PHS National Water Quality Network and the parallel systems of State and interstate agencies. In a more remote sense, it led to this symposium in which we are participating.

A great deal of data is now being collected. Perhaps as a result of the deliberations of this Symposium we will be better able to assess the usefulness of these data.

We believe we are progressing with respect to detection of certain types of pollution. Recent improvements in sampling and analytical techniques for coliform organisms and enterococci permit us to discern fecal contamination more readily than before. The successful development of equipment for continuous recording of dissolved oxygen represents a significant advance in the monitoring of streams for oxygen-demanding wastes. The current emphasis on radioactivity monitoring is providing steadily improved instrumentation for this program. However, many important shortcomings remain.

There is a growing and important need for an improved method of capturing and identifying soluble organic compounds in water. At the present time a carbon filter which was designed and developed by the Sanitary Engineering Center is being widely used. We are naturally pleased at this recognition of the carbon filter, but we are aware that it possesses shortcomings as a sampling device and that it must be supplemented by other techniques. Perhaps the greatest drawback in any device using carbon for sampling purposes is the difficulty with which many adsorbed organics are released. Beyond this, there is the enormous problem faced by the organic chemists charged with the responsibility of resolving complex "gunk" into its component compounds.

I should not leave this subject of monitoring water quality without reference to our failure to date to utilize effectively the biological indicators of pollution. Aquatic biologists insist that aquatic life is very sensitive to changes in water quality and they urge us to learn how to use these indicators. However, to date our use of biological indicators of pollution is relatively crude and expensive.

It must be re-emphasized that collection of data is not important if they do not relate to water quality. The time is ripe for close, critical scrutiny of the kind of information now being recorded in water quality basic data programs.

CAN WE EFFECTIVELY TREAT POLLUTED WATER FOR REUSE?

The main function of the modern water treatment plant is to remove particles suspended in the water, and to destroy microorganisms that manage to survive flocculation and filtration procedures. Except for removal of hardness, little attempt is made to remove soluble chemicals in drinking water. Where taste and odor are highly objectionable, carbon is usually applied. But carbon is selective in its action, and sometimes it is ineffective. We actually know little about the principle of adsorption as it applies to the use of carbon. Moreover, there is no assurance that harmful substances in solution will signify their presence by producing taste and odor. Here, as in waste treatment, interesting research opportunities exist.

Let me summarize my evaluation. I have considered the following water quality protection techniques:

1. Accounting for all pollution reaching a body of water.

2. Predicting the pollutional effects of a given waste.

3. Treating waste to prevent pollution.

4. Using the stream effectively and economically in waste disposal.

5. Monitoring the receiving stream intelligently.

6. Treating contaminated water for reuse effectively and economically.

In my opinion, these steps encompass all measures necessary to a sound control of water pollution. Mastery of these steps assures adequate protection of water quality. I would express my belief that the use of these techniques falls short of mastery.

I should like to point out that difficulty in separating polluting substances from water is a weakness common to many of the basic techniques in water quality protection. It is particularly apparent in chemical characterization of complex wastes, in treatment of wastes and water, and in monitoring receiving waters.

It is timely that we aggressively advance the development of new separatory techniques. In doing this we should note carefully the contributions the physical chemists may make to our field. Of particular interest are developments in modified adsorption, chromatography, foam fractionation, freezing, direct solvent extraction, and ion exchange. These by no means exhaust the list of physical chemical principles that may ultimately be applied with profit to the solution of our problems.

I have painted a somber picture in evaluating our ability to control water quality. I hope you understand that my evaluation was presented in a framework of research. This was done because the problems I have discussed are more problems of the future than of the past and present, although here and there we have already encountered them.

We are faced with problems of great research challenge. We can face them with confidence.

HARVESTING WATER QUALITY DATA

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Recent expressions by some of the thinkers of our times have emphasized the impact of science and technology on today's world. One British writer, C. P. Snow, in his interesting essay, "Two Cultures And The Scientific Revolution," suggests that maybe the impact of scientific thought upon the non-scientific world is not indeed as great as it should be. Snow feels that there is almost no communication between the scientific and the non-scientific worlds, and he considers that this intellectual gulf is among the most serious problems of our society. He feels that while scientists and technical people are in a minority, their efforts will shape the course of future events and that we must bridge this gulf effectively if we are going to solve the problems of the future.

Perhaps we who are concerned with the control of water pollution are confronted at least in part with the same problem. If the non-technical person should attempt to size up our problem, he would most likely ask, "Is this stream polluted?" The technical person would ask, "How polluted is this stream?

What caused the pollution? What uses of the stream are likely to be affected?"

In other words, the refinement of the questions asked by the technical person tends to obliterate the answer which the non-technical person wants. Water resource planning, stream classifications, and water quality studies are things which tend to be rather mystifying to the non-technical person. Indeed, even we professionals find ourselves confused by the debates of distinguished sanitary engineers concerning the question as to how to properly evaluate a water pollution control program. It is perhaps amazing that we have come so far in water pollution control without really agreeing on any one way of evaluating our progress. We seem to be perfecting elaborate schemes for getting continuously recorded water quality data and for communicating this information rapidly by radio and even tele-metering, without really finding out how we are doing in water pollution control. The important measures of progress in water pollution control are observable not in a matter of minutes, but only over a period of years. In order to evaluate changes in water quality, we must of course have water quality data. In most cases the data we need has been collected, but we do not use it. Why don't we use it? We don't use it because much of it is not readily available. It takes a great deal of work to make it available and meaningful.

Many agencies and organizations collect water quality data for many reasons. In one seventy-five mile stretch of river on the Eastern seaboard of the United States, it is estimated that the following groups have collected or are collecting water quality data:

3 federal agencies
1 interstate agency
5 state agencies representing 3 states
20 industries
7 water works
7 sewage works
3 consulting and research groups
—
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A great deal of work has been done on this particular river to abate pollution, but its pollution problems are by no means solved. One wonders how much more data needs to be collected to support the solution of these problems. Certainly it is true that all the data which has been collected is not available to all who need it. No doubt there has also been some duplication of effort. This represents a serious economic waste. At least one reason why the pollution problems of this river have not all been solved is that the agencies whose job it is don't have all the data that has been collected. In order to solve this problem, these agencies may decide that it is less trouble to go ahead and collect more of their own samples than to look into the availability of the needed data from nearly fifty sources. This results in a waste of our already limited resource of field and laboratory personnel in water pollution control.

Representatives of the non-technical sector of society when they ask the question, "Is the stream polluted?" rarely get their answer. This would appear to be for two basic reasons: (1) lack of readily available data, and (2) lack of water quality criteria. The latter problem, the lack of nationally accepted water quality criteria, is as pressing as the problem of availability of data. While there is no time now to explore this question, it is urgent that we find an answer to it soon.

The picture which I have described is repeated for other rivers. Intentions to do something about pollution problems have too often resulted in resolutions to make one more study, to collect one more set of up-to-date data, before making the big push to abate pollution.

What then can be done to improve this situation? Often the need for collecting more samples would be eliminated if we had readily available to us all the reliable data that had already been collected on a stream. In order to accomplish this, we would have to agree on a uniform method of reporting data and on the establishment of a water quality clearinghouse which would serve as a national memory and source of water quality information.

Modern methods of data processing, storage and tabulation have made the establishment of a national clearinghouse on water quality data much more feasible than it was in the past.

Just consider the value such a clearinghouse would have to government units at all levels who are concerned with water conservation and water pollution control. Such a clearinghouse would be of equal benefit to industrial water users, consulting engineers, water works and many others who need water quality data for treatment plants, design control and studies, reports and plans. Changes in water quality of streams or sectors of streams could be tabulated and analysed with an efficiency and speed heretofore unknown.

The establishment of such a clearinghouse would not be an easy matter. It would indeed present some problems. Here are some of them:

UNIFORM METHODS OF ANALYSES

Luckily our professional forefathers have long ago seen the need for the establishment of uniform analytical methods. This job has been well taken care of. The Analytical Reference Service of the Robert A. Taft Sanitary Engineering Center has been a great boon in the further standardization of laboratory work. Anyone who would participate in such a clearinghouse would obviously have to meet certain criteria of performance in regard to laboratory work.

UNIFORM METHODS OF REPORTING

Here we would have a job of agreeing upon a uniform method of reporting analytical data, drainage basins, streams, laboratories, sampling stations, etc.

DEVELOPMENT OF THE CLEARINGHOUSE SYSTEM

There would appear to be at least two possible schemes for establishing a clearinghouse system. One would be the possibility of having state or regional data clearing stations receive and store data for certain geographic regions and also service a national clearinghouse. The other would be to have one national clearinghouse serve the entire country.

Since the Public Health Service has the primary responsibility in water pollution control at the federal level and since it has already assumed leadership in this field by establishing a national water quality network, it seems logical to hope that that agency could assume the basic responsibility in the clearinghouse function also. It is important to say at this point that this type of endeavor is a cooperative one, and in order to be successful will need the helping hand of governmental agencies at all levels and of many other groups.

FEEDING DATA TO THE CLEARINGHOUSE

A. Current Data - This would involve sending to the clearinghouse copies of all water quality analyses currently made by participating groups on a prescribed form or in the form of a prescribed punch card. This would not require taking any samples which are not now collected. It would simply be a matter of sending copies.

B. Past Data - In our various filing cabinets and reports, there exists a storehouse of water quality data undoubtedly worth many millions of dollars. To unearth this data and to make it available would be of great value to any proposed clearinghouse operation, but it would also be costly in terms of clerical time necessary to prepare the data for transmission. This is an area where volunteer workers might make a real contribution to our water resource planning efforts.

In Pennsylvania our Federation of Sportsmen's Clubs is providing us with valuable help by assisting in the reporting and investigation of fish kills. We have had some indication that we might also obtain their assistance on a voluntary basis in the preparation of water quality data for mechanical handling. This, of course, could only be done after thorough and careful training.

The job of establishing a national clearinghouse on water quality would not be an easy one, but it would be important, perhaps essential, for continued progress in water pollution control.

Perhaps I was mistaken in using an agricultural analogy in the title of this discussion. Perhaps it would have been better to use an archeological one, because as part of this proposal, we would indeed be unearthing a lot of valuable water quality information and reconstructing a lot of history in this field.

Norbert Wiener has put it very aptly "to live effectively is to live with adequate information." Our progress in cleaning up our streams has only in a few cases been so dramatic as to engender much public recognition and support for our continuing efforts. We must improve our methods of communicating among ourselves and with the public on the cleanliness of our streams. Perhaps, too, we are spending too much time collecting data and too little abating pollution. This proposal is intended to improve our information concerning water quality and in doing so, make our efforts in conserving our water resources more effective.

ROLE OF WATER QUALITY DATA

DISCUSSION

MR. ROBERT S. INGOLS (Director, School of Applied Biology, Georgia Institute of Technology): I was particularly interested in the ten beneficial uses which Dr. MeKee listed: I do not recall that he mentioned hydraulic power and its effect and correlation with water quality downstream and its effect upon pollution acceptance upstream or at the site of the impoundment.

This is a major problem in each of the Southeastern Atlantic States which have well developed hydraulic power programs. One river has 10 dams sequentially downstream where there isn't more than a mile between the dam upstream and the impoundment downstream. The effect of this upon water standards, as promulgated by State Water Pollution Control agencies, is a very serious problem to those of us who have to work with the consulting engineers in trying to advise them as to what degree of treatment is needed for pollution acceptance in some of these situations.

The problem of hydraulic power generation is a criterion, or is a factor that should be very carefully evaluated in a water use picture.

DR. McKEE: I completely agree. I did, however, mention water power as one of the ten beneficial uses of water.

MR. INGOLS: You mentioned thermal generation and I assumed then that that was simply water condenser cooling.

DR. McKEE: Oh no, I was thinking of water, hydraulic water power. I listed water navigation and boating and so on in a collective group. However, I certainly agree with you that the effects of impoundments upon water quality represents one of our big areas of ignorance. We certainly need to know a lot more about that.

DR. BERNARD NEWMAN: (Director Newing Laboratories, Inc., Islip, New York): Dr. McKee mentioned definitions of standards and criteria and in doing so he mentioned either advertently or inadvertently the Public Health Service standards for drinking water. Now in these so-called standards there are specific recommendations on, for example, iron and manganese. I think recommendations for water quality criteria would be a good term to define. Now in regard to this standard, as you call it, of .05 parts per million for hexavalent chromium; in our area we have a town called Farmingdale which Dr McKee described very nicely in his book. The Farmingdale aquifer has been polluted by plating wastes from one of the airplane plants, and there are several families around the fringe of this plant who are drinking water which has between 25 and 35 parts per million hexavalent chromium with no apparent ill effects. They have gotten so tired of people going over to take samples of their water and looking at them that they now forbid anybody to touch their wells. But at the last test it ran that high.

DR. McKEE: You asked about defining or using a definition for recommendation. You also refer to the Public Health Service drinking water standards. I refer to them as standards involving mandatory and non-mandatory provisions, and the iron and manganese, for example, is non-mandatory but the hexavalent chromium is a mandatory one.

MR. HAROLD ROMER (Director, Bureau of Sanitary Engineering, New York City Department of Health): I would like to make particular comment about one of the items Professor McKee has raised. I am very much concerned with the question of the epidemiology and the importance of the bacteriology of bathing waters. I think data collection is one of the real weak points in the lack of pertinent and relative data on the epidemiology of bathing waters. So, before we condemn the importance of bacteriology in bathing waters, I think we ought to investigate the subject much more.

The City of New York currently is interested in doing an epidemiological study which has statistical significance. I have discussed with many people the work that has been done in various places and what we can do to try to resolve this problem.

Everyone seems to agree that we actually have not studied this problem in a reasonably scientific manner and that we have not gathered sufficient significant information.

Perhaps there are some of us who fear that if we study this problem we will come up with a negative. This fear has been expressed rather broadly, perhaps in a veiled manner, but expressed nevertheless. I believe that most of us would like to know what the facts are. New York City is an ideal field laboratory for this type of study because we have extremely good and extremely bad waters where large numbers of people bathe. But I would like to see a lot more of us try to get the "facts of life" about this problem, rather than skirting it with standards, and by not collecting data on this subject.

DR. McKEE: Again I have to be in complete agreement with the speaker. I hope there wasn't any difference at all in my original presentation. I mentioned this as an example of an arbitrary standard that has been set up. In California, for example, the salt water bathing standard is 10 coliforms per millimeter, and that is rigidly enforced. It was set up as a standard of convenience.

Now I agree with you. We need a lot more study on this thing, and I would never object to further research on any of these subjects. I do object, however, to people who have a standard and therefore discourage any further research for fear, as you pointed out, that the research might reveal that the standard is too strict.

MR. DAVID E. BARRY (Assistant Superintendent of Environmental Sanitation, Milwaukee Health Department): We are working along the same lines as New York. Our problem is particularly bathing beaches. I am very interested in knowing more about these bacteriological standards for water. Does the 10 coliforms per milliliter mean a media count that can never be exceeded, a logarithmic average of MPN'S, Phelp's Index, or what?

DR. McKEE: In California it is based on the most probable number. The membrane filter technique is not accepted for this purpose. This figure of 10 coliforms per milliliter cannot be exceeded in more than 20 per cent of the samples, nor in any four consecutive samples. Along any stretch of beach, it is necessary to take many samples. For example, if only one sample a week is taken most of the summer may be over before it can be determined, if 20 per cent of them are in violation. If it can be seen at the beginning that four consecutive samples would exceed the standard, then it is a good provision.

MR. T. E. LARSON (Chemistry Section, Illinois State Water Survey, Urbana, Illinois): This is out of my field, but I am concerned with how far it can be exceeded in any one sample.

DR. McKEE: There is no regulation on that. You can have billions in one sample.

MR. ROY NELSON (I.T.T. Kellogg, Chicago, Illinois): Dr. Hollis, is this the first gathering of this nature of the various sections that are represented here?

DR. HOLLIS: I don't think so. I think we have debated on this at various meetings but this is the first, to my knowledge, that focused right on water quality measurement as such.

MR. NELSON: Reflecting on the statements made by the various speakers this morning, it would appear that a world of difference exists amongst the various facets represented here and that from this group should be formed some sort of Committee for communication within itself. I think something should be formed from this Symposium so that after the ideas being germinated here are allowed to run through these various intelligence levels it can be determined what then can be the approach.

CHAIRMAN HOLLIS: Walter Lyon tells the story of two men meeting on the street and one of them congratulating the other one on the birth of a daughter last Wednesday afternoon. The man took the congratulations, but he said he had one serious problem; the child was born at high noon. The question was, should the birth be registered on the fourteenth or the sixteenth, and this had created quite a disturbance in his family, and elsewhere. And the other one somewhat perplexed wondered "Why don't you register it on the fifteenth when it occurred?" And this seemed to solve the whole problem.

Now Walter has told me that he doesn't think there is any basic difference between some of the arguments I have tried to advance and some that others have tried to advance that appeared to be in disagreement. But my argument can be put very simply; that I would agree fully that we need, and need desperately, to have common denominators that we agree upon, and unless we do, then how do we expect a non-scientific public, as one speaker referred to it - or I would put it, the scientific fraternity in fields other than ours - to understand just what the problems of pollution are. We heard some of the differences advanced here this morning. I agree with you that there is need for better communication among ourselves.

PROFESSOR M. A. SHAPIRO (University of Pittsburgh): One of the things that has concerned me is that while the State of Pennsylvania will accept an MPN of 1000 coliforms per 100 milliliters per sample for a natural bathing place, the standard for a swimming pool is one coliform organism for 100 ml's. What is the difference?

MR. LYONS: This standard has some obvious resemblance to reasonableness but it brings up the issue of what has been discussed here. Scientists and researchers often criticize administrators for having what would appear to be ridiculous standards, but yet the scientists and researchers are not giving us the answers on which to base better standards.

In the case of a swimming pool, where there is a disinfectant involved we can have a different kind of a standard because of the proximity of bathers to each other, and the volume of water in relation to the bather load. The situation in a swimming pool is entirely different bacteriologically than it is in a natural bathing place where the volume of water is presumably large enough, so that mechanical and chemical methods of purification are not required.

MR. SHAPIRO: I would like to point out that in at least two cases now in the State of Pennsylvania they are chlorinating the lakes and recirculating the water.

MR. LYONS: I will be glad to comment on that point. In a situation like that, in Pennsylvania, and I think this is true in other states too, this is done on an optional basis. In other words when a state or city agency approves a natural bathing place, it evaluates the bathing load, the flow of water, the volume of water, and if, in its opinion, the bathing place is safe without purification, then it will permit the use of that bathing place. Now in some cases this is done on a voluntary basis, the people do it voluntarily. If it is necessary for public health reasons, then there should be a swimming pool in that place and not a natural bathing place.

DR. McKEE: I think that the situation on the bathing waters is not nearly as critical as that concerning shellfish. According to the drinking water standards the coliform concentration has to be less than one per 100 milliliters but in the waters overlying oyster beds I recall that the water can have 70 coliforms per hundred milliliters. Now the oyster is a vacuum cleaner, i.e. it is a cleaning device, and if there are 70 coliforms per 100 milliliters in the overlying water, I am quite sure that an oyster taken from those waters would have a whole lot more than 70 per hundred milliliters in the shell liquor. I believe I could go to the local shellfish market, shuck the oysters and analyze the shell liquor and I would find something in the order of perhaps 1,000, 10,000 or 100,000 coliforms per hundred milliliters. Yet this same consumer is not allowed to have more than one coliform per 100 in his drinking water.

MR. SAM FAUST (Assistant Professor of Sanitation, Rutgers University): Well that raises the question: why coliforms?

CHAIRMAN HOLLIS: I presume the answer is that it is the best parameter we have at the moment.

MR. RICHARD S. FOSTER (Manager, Aquatic Biology, General Electric Co., Richland, Washington): This question is perhaps a little more administrative or political than technical, although it goes back to a technical basis. We have heard quite a bit this morning about the need for establishing proper water quality for receiving streams and problems of measuring these and also the needs for control at the various plants which are putting out the effluent. I wonder what our state of thinking or tendencies are in terms of the direction of going as far as apportioning the amount of material coming out from multiple discharges into the same stream. How do you go about the problem here of deciding what particular industry or municipality is going to put out how much, and without exceeding the total capacity? How do you distribute it?

MR. BERGER: I don't think there is an answer to that unless you consider the whole complex of industry as a single plant.

MR. JOHN C. GEYER (Professor of Sanitary Engineering, Johns Hopkins University, Baltimore, Maryland): This comment is stimulated by something that Dr. McKee said to the effect that water quality criteria should be related to some beneficial use. I would certainly agree with this statement and obviously we have to measure some qualities of water in order to have criteria for governing what the water should be. But this brings up a point as to what else you might want to make quality measurements for. It seems to me that this matter of criteria and standards have directed the whole profession away from measuring quality just to determine what is going on in the water, to learn more about the water itself, and the phenomena that take place in it. The oceanographers study the oceans not in relation to any beneficial use, except in special cases, but in general their interest is finding out what goes on in the ocean. They make enormous numbers of dissolved oxygen measurements for example, in the Atlantic, and the purpose of these analyses is to attempt to determine the age of the water, and thus get some idea of its rate of circulation. This is done basically to have a better understanding of the various phenomena in the ocean. And because of this scientific or basic approach which the oceanographers have taken, it seems to me we are finding ourselves in the position of turning more and more to them for help and advice on what to do about our rivers. Understanding has to come before reason, and when we talk about quality measurements we ought not overlook the fact that these may need to be made for the purpose just of learning what is going on, to get a better understanding, without regard to any criteria or pollution problems or anything of this sort.

DR. McKEE: I certainly don't disagree with the basic premise on that. I do feel, however, that it is oftentimes necessary to separate research as one function, and regulatory activities as another, and the question is should regulatory agencies, who are in the monitoring business, also be doing research, or should they be gathering research data? This is a question that can be debated.

MR. WARREN J. KAUFMAN (Associate Professor of Sanitary Engineering, University of California, Berkeley, California): Mr. Lyon stated that local groups examined the swimming pools and determined the situation was a safe one.

MR. LYON: Well of course the obvious answer is that with a few exceptions we don't know what is a safe level of these contaminants. And this is the point that we administrators have to struggle with, because people want to know whether a certain swimming pool is safe. So we come up with these sometimes quite arbitrary standards based on either what other people are doing or what somebody thought of, and unless the research people give us the answers, we are forced sometimes to use rather arbitrary assumptions.

DR. BERNARD NEWMAN: The Food and Drug Administration administers a recently enacted law whereby a firm which adds either a food additive or puts out a drug has to first show that it is safe and harmless. Do you think we will ever get to a state where the industry which is dumping the stuff into the stream will have to show that the waste can be dumped instead of having public funds used for the purpose of safeguarding the stream from the industry's waste?

CHAIRMAN HOLLIS: This comes up quite frequently when members of Congress ask why should there be an appropriation, for example, for water pollution? Why don't we legislate out all waste on the rationale that we have reached the point in development when cities and industries should be prohibited from dumping anything into the streams that adversely affects the public welfare? And in the minds of a Congressman, or to me, this is an understandable thing; I think we would all shudder at the thought --

DR. NEWMAN: I don't mean that, I mean if they can show that the waste can be put into the stream with perfect safety, fine. But we don't even know the structure of some of these new compounds.

CHAIRMAN HOLLIS: I suspect they too would have difficulty. For example, you have the matter of all synergisms and compounds. We used to think of safety in public health as something you could measure as an acute effect; the acute illness that is measurable in vital statistics. But now we are beginning to wonder if the word "safe" doesn't have a much broader, more subtle meaning -- physiological impacts, long term low concentration effects, and this sort of thing. Much of that which some of the speakers were commenting on this morning needs investigation.

DR. McKEE: I would hate to see the day come when every municipality and every industry had to prove that each constituent of its waste was absolutely safe before it could discharge it. I don't think there is an analogy here with food additives. They are a different situation. The food industry produces natural products, which are consumed, as it has since the beginning of man. When they employ a special kind of a coloring to make it sell better, for example, they color the oranges in Florida so they will look like California oranges, then I completely agree that that industry should have to prove first that it is safe. But I don't feel, that the same thing applies to dischargers. There are several reasons.

I go back to the tenet of law which says that a man is innocent until he is proved guilty, and I would like to say that as far as I am concerned discharges should be considered innocent until somebody can prove that they are guilty. It is because I believe that waste disposal is one of the beneficial uses of our stream. It is a tremendous economic asset for a community or an industry to be able to discharge its waste to a river, and if it can do so without harming a beneficial use, it should be allowed to do so.

CHAIRMAN HOLLIS: This is one of the points of disagreement here, that "if". Historically in Public Health practice if we had waited in each case for conclusive proof of damage of some of the impacts on public health we would certainly not be where we are now. The outstanding example, of course, is Chadwick's movement in England long before we knew what a germ was, the association of filth and disease. So here you have the two extremes, and I think somewhere between these two are hard choices.

MR. EDWARD J. CLEARY (Executive Director and Chief Engineer, ORSANCO, Cincinnati, Ohio): I would like to take violent disagreement with Dr. McKee's philosophy. I do it from a sense of frustration. Back in 1951, ORSANCO was drafting some basic requirements in the discharge of stream waste. One of the proposals was that no toxic waste shall be discharged. We investigated every state law that has been written on what is toxic. So ORSANCO addressed itself to that question and the Commission and industry advisors took the position that it would be an unfortunate step to place the burden of proof upon industry at this time. So ORSANCO then devoted part of its money from the Public Health Service to the physiological aspects of water quality; that was the exact title of our contract. We carried on this work for some five years at the Kettering Institute at the University of Cincinnati. I think you are all aware, as is the gentleman that raised the question, that this is a highly expensive business. With the hundreds of new compounds being developed yearly one could hardly catch up on the job. ORSANCO didn't anticipate it was going to find all the answers, but it did feel a start should be made in this direction to determine how much work was involved, and to determine the subtle potential toxicity implications of some of these things. We spent over a quarter of a million dollars and we have gotten relatively little information and certainly we are just as far behind now as when we started with all the new compounds that have been developed.

I see nothing unfair in requiring that an industry which seeks the privilege of using the primitive capacity of a stream provide some evidence as to the potential toxicity of that which they are proposing to dispose of. If I were to follow through on Dr. McKee's philosophy completely, the evidence would only come in when some one toppled over dead in the stream. I don't think we want to go that far. And so I must find myself in disagreement, and feel that it would not be an unfair burden on an industry to make such tests as might be necessary to determine at least within reasonable limits what the toxic implications are, and to provide that information to state health agencies, and the state health agency then can evaluate it.

There is a conference next week (September 5th) to probe this question further on the physiological aspects. We hoped for a long time that something like this would come along because we do feel that perhaps in the field of toxicology, as in the field of radiation, some maximum permissible concentrations may be set up as a guide to administrators.

MR. JOSEPH D. HELWIG (Atlantic Refining Co., Philadelphia, Pa.): What industry would like would be some idea as to what is meant by "indication that the discharges are not toxic". We have been talking about economics coming into the picture. If you accept what Mr. Berger said, it costs nearly $50,000 for each compound; and you say each industry is supposed to know what the toxicity of the chemicals that they are using amounts to? Multiply that by a hundred or a thousand industries using the same chemicals; so you mean for each one to check on the toxicity of that? This is what it implies; that each industry that uses every compound knows what its toxicity limits are. Multiply $50,000 by a thousand industries, and you have fifty million dollars that is all duplicated effort. Where do we go? How far do we resolve that economic aspect?

CHAIRMAN HOLLIS: That may be a good question to halt the discussion on, our time is up.

But before we adjourn -- this is unfair and I concede it -- we have amongst us this morning a gentleman from Australia, Dr. Michael Flynn. He is a physician, but he thinks so much like an engineer that we are going to consider him a colleague. Dr. Flynn, you have heard the many different points of view and observed the setting as we carry it on. You might wonder where it all leads to, but this multiplied by other meetings is how we make progress. It isn't as gloomy as it sounds, but this is the way of shaking down, and I wonder what your point of view would be on some of this.

DR. M. J. FLYNN (Chief Medical Officer, Sydney Water Board, Australia): Thank you, Dr. Hollis, for your welcome. I would just like to say how much I have enjoyed the discussion this morning. It has been a real eye-opener to me. I would like to go back to the Bible. I am not a Bible expert, but if we truly believe in the concept of love thy neighbor, we should believe in the concept and principle of stream equity, not the principle of stream acceptance. The latter simply means we go back to the times of the Elizabethans when they used the streets for the emptying of their slop buckets. What we are doing at the moment, apparently, is to use the streams in this manner. This, if I "read" Dr. McKee correctly, is just a method of discharging uncontrolled waste, because truly he has admitted, as everybody else has today, that we don't know what the meaning of many of these wastes are, and how to measure them. So let's look at the concept of stream equity. As far as it is economical and practical, and I think it truly is, if a consumer takes water from any source, then he should return it to the river in at least the same quality as he gets it.

UTILIZATION OF WATER QUALITY DATA

Chairman: S. KENNETH LOVE,
Chief, Quality of Water Branch,
U. S. Geological Survey, Wash., D.C.

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PHYSICAL AND CHEMICAL PARAMETERS

By T. E. LARSON, Head,
Chemistry Section, Illinois State Water Survey,
Urbana, Illinois

One could go a long way back in history and trace the growth of interest in the examination of water, but it probably all started with man's reaction to the sight, taste, and smell of the water he drank. Through the centuries from as early as 2000 B.C., "medical" lore is scattered with quotations on ways of filtering and storing water.

In 1880, the National Board of Health in the United States began an extensive study of tests which had been proposed up to that time for the detection of pollution in water. The tests included chloride, nitrite, nitrate, ammonia, and particularly carbon and albuminoid ammonia.

Attempts were also made to correlate bacteriological examinations with chemical data, but the bacteriological methods available at that time discouraged routine examination.

J. W. Mallet, who directed this work, however, was convinced that the danger of pollution lay not in some chemical substance capable of causing disease but rather in the presence of living organisms in the organic matter carried by these waters.

In the Annual Report of the Board of Health in 1882, he concluded that it was impossible to judge the sanitary character of drinking water by any of the available chemical methods of analysis, and that priority on judgment should be given to the source and history of the water supply, with chemical evidence as supplementary data.

(Although the first Drinking Water Standards in 1914 recognized the importance of the source and handling of the water supply, it was not written into the Standards until 1925 in terms of "Source and Protection." This aspect has been steadily strengthened in subsequent revisions.)

Mallet also concluded that although there were no sound grounds for establishing standards of purity based on chemical analyses, the analyses served two legitimate purposes, namely: "The discovery of the unusual character of a water supply so that suspicious changes can be detected and traced; and the detection of gross pollution, such as occurs with injury to pipes and extensive leakage of drains."

Among several other conclusions, one is added here as pertinent to the present subject in a broad sense: "Local standards of purity based upon sufficiently thorough and repeated examinations may be established."

In 1905, following by ten years the move by bacteriologists to secure the adoption of more uniform and efficient bacteriological methods, the First Edition of Standard Methods of Water Analysis was published, as a Report to the Laboratory Section of the American Public Health Association. This edition included some 30 tests for physical and chemical components in water as well as procedures for bacteriologic and microscopic examination.

Currently the Eleventh Edition (in press) includes more than 50 determinations. Some of the more notable additions in the interim have been determinations of pH, BOD, COD, chlorine demand, selenium, phenol, chromium, cyanide, cadmium, arsenic, fluoride, ABS, and radionuclides.

(Bacteriological) Drinking Water Standards were adopted in 1914 by the Treasury Department and revised in 1925. The revisions by the Public Health Service in 1942 and 1946 are currently being up-dated in view of technological developments since 1946.

This very brief and incomplete history appears to be appropriate for the purpose of this discussion on physical and chemical parameters. The assignment here is to discuss

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the value and other related aspects of these parameters, both conventional and new, and to cite their possible shortcomings.

USE OF WATER

It would be presumptuous to attempt to discuss in detail the validity, significance, and shortcomings of each of the determinations which are available today. Rather, it is planned first to provide a broad coverage of the related aspects of sampling and the intended use of the water. These in turn are also related to each other. A broad classification of water use may include domestic, agricultural, industrial, recreational, (fish, game, wildlife), commercial power transportation (shipping), aquifer recharge, and waste disposal and purification.

It is rather pointless to specify the parameters for each of these uses, because within each of these categories there may be several subdivisions or specific items of primary interest. A degree of judgment is therefore needed to designate the essential parameters requiring the least amount of time and effort.

Some determinations are superfluous for one use but highly essential for another. For some uses, the requirements in quality data may be essentially nonexistent or the restrictions may be such that only a gross estimate of dissolved solids is required; transportation use would be one such sample. Other uses have such limiting specifications that only the most drastic treatment can provide the required quality regardless of water source--for example, television tube manufacture. In quality for domestic drinking water, accepted Standards prescribe mandatory limits for prevention of disease by organisms and for protection from toxic agents, and include recommended limits for substances which may be offensive to sight, taste, and smell.

Aquifer recharge is listed as perhaps an unusual or narrow classification. We recently had occasion to outline the desirable features involved in this water use.

Quality Parameters for Recharge Water

1. Turbidity (for design criteria)
2. Temperature < 65° (Conditional)
3. pH (6-8)
4. D.O.
5. B.O.D.
6. Syndets (10)
7. and Drinking Water Standards (for dissolved minerals, Fluoride, Nitrate, heavy metals and radioactivity)

Certainly some of these have greater priority than others, and in emergency, with recognition of hazards and potential problems, influences from a limited amount of previous data may serve as guides for the collection of essential supplementary data.

OBJECTIVES OF SURVEY

A sampling program may also be concerned with surveys designed for any of several objectives: resource data, monitoring, surveys for design purposes, plant or process control, distribution-system quality monitoring, and trouble investigation.

Each objective may require a sampling program of distinct design. The frequency of the sampling may range from a few periodic samples to continuous recordings of selected parameters. Grab samples may be obtained for separate analysis at rather uniformly timed intervals, or composited with recognition that quality variations and abnormalities are masked to the extent that the unit samples are composited.

Under known conditions for limited periods, the uniform interval between samples may be shortened to obtain greater definition of quality changes that may occur.

The frequency of collection of samples can also depend on the past history and geographic distribution of normal information from other analyses. You will recall that this was one of the legitimate purposes for chemical analyses indicated by Mallet, namely: to discover the unusual character of a water supply so that suspicious changes can be detected and traced.

Historically, the water character at a particular representative sampling point on a stream may have shown each of the parameters to vary within certain descriptive limits for 80, 90, or 98 percent of the samples, and to have a fairly well defined median value for each. Any level within the assembled and ranked data thus approaches the unusual to the extent that the probability of occurrence approaches zero.

Paradoxically, a sampling program cannot be evaluated without a minimum of records over a reasonable period. It then becomes desirable to evaluate the data statistically and, by such multiple correlation as may be possible, to determine the need for extending the period of observation.

Without sufficient historical data, of course, this cannot be done. As an alternate approach in such case, some degree of evaluation may be deduced from historical data from other locations. However, this can be hazardous.

REPRESENTATIVENESS

As another aspect of sampling it must be recognized that an analytical determination is just that, and hardly more, without adequate assurance that the portion of the sample was representative, that the sample itself was representative at the time of collection, that the time of collection was representative for any other time at the same location, and that the location was representative of a geographic area or a geologic aquifer.

Of considerable value in determining the representativeness of the sample is the data on date, time, location of sampling point, and temperature, which should accompany the sample. For stream samples, the streamflow or river stage record is important supplementary data; and for well samples, the pumping rates, nonpumping and pumping levels, and duration of pumping prior to collection of the samples are important assets. For distribution system samples, appropriate data and the personal observations by the collector are also of primary importance. For some determinations, it is advisable to perform and report field tests made at the time of collection (viz., soluble iron, pH, odor, D.O., etc.).

In monitoring and most other survey work, the cost of collection and transport of samples may often be greater than the cost of the actual analyses.

Therefore, great value at the cost of minor effort may be realized from supplementary data, such as a report of an unusual or transient odor or appearance of the water. The meticulousness of the report accompanying the sample is often equal in importance to the recorded observations of the unusual by the well trained analyst.

Although it is often said that there is no such thing as too much data, there are instances where a sampling point may be oversampled or over-analyzed. There is little point in placing a continuous recorder for hardness on a well discharge which has been shown by a few appropriate grab samples to have no variation in hardness. More particularly, the determination of the concentration of a parameter by means of a highly accurate but costly procedure is not warranted where the significance is minor and a reasonable estimate can be inferred from other determinations. The gravimetric determination of sodium on a routine monitoring program would be an example of such wasted effort.

For well waters from an artesian aquifer, the quality rarely varies, even within a wide geographic area. Variations in concentrations of components may be expected, however, for wells subject to seasonal recharge, to entrance of waters from more than one aquifer, to pollution, to casing failure, and to corrosion of metallic features.

SHORTCOMINGS

Specifically, what are the shortcomings of the physical and chemical parameters? It would appear that if each serves its singular purpose and cannot be further simplified, then there are no shortcomings. Some determinations in Standard Methods are tedious and time consuming for purposes where only a general idea of concentration is desired. For instance, and I can be condemned, a plus or minus 10 percent (or even 20 percent) error in the iron determination could permit a less rigid procedure. Boiler feedwater treatment control procedures, for example, have been simplified by the use of less vigorous but suitable analytical procedures for the necessary determinations. Reagents may in some cases be combined. Solid acids and combinations of powdered reagents in pellets with a simple colorimeter can often provide untrained personnel with a tool which will serve their purpose as well as a prescribed delicate procedure that challenges the techniques of even a trained analytical chemist. However, the supervisor must make himself aware of the chemistry of these simplifications and evaluate the limits of applicability of these short-cuts.

It is a reasonable postulate that a well trained chemist is wasted on routine control tests that are over-designed for the job. His duties should be limited to supervision of this work, freeing him for review of current literature, for research on other problems of analysis and treatment, or for the performance of the more sophisticated analytical tasks.

In supervision, it is the responsibility of the self-respecting chemist to evaluate the procedures used in his laboratory, not only in the light of efficiency according to the purpose for which the determinations are being made, but also for accuracy.

With the remarkable improvement in photometric techniques, the time has come when the chemist must prescribe the most simple, yet careful, method for preparation of the sample which can be performed by almost anyone who can read a dial on an instrument. Here again the chemist must recognize and avoid the trap of accepting a dial reading as gospel, however well read, for many slips can occur in the sample treatment and handling of the photometer. The results must be evaluated with this knowledge that comes from training and experience. For instance, a good chemist will not accept a pH reading as valid, knowing that the alkalinity concentration affects the degree of change of pH with temperature. (I have yet to understand how a single dial on a pH meter which is set to the temperature of the water, will convert the true pH at that temperature to what it would be at 25°C whether the water has 10 ppm alkalinity or 300 ppm alkalinity. Oddly enough, the literature and instructions provided with the meter make no mention or reference to this; but strong claims are always made for an "accuracy" -- or sometimes "reproducibility" -- to ±0.05 pH unit.)

A good chemist will also look askance at results which may be altered by prolonged storage before analysis (viz., NH_3, NO_3, NO_2, SiO_2, Alk, Hd, BOD, pH, etc.)

The procedures in Standard Methods are described and outlined as the best available for the usual purpose and serve, as do all, a very useful purpose, even though out of date by time of publication.

This does not mean that they cannot be simplified for more practical use. Nor does it mean that they cannot be made more sensitive and accurate for special purposes when needed. This can often be a challenge to the ingenuity of the chemist, requiring his concentrated effort. Currently there is an ABS determination in the new Standard Methods that is recognized as inadequate. I have no doubt that this determination will be improved or a new procedure devised in the future. The history of the test for chlorine (or for nitrate for that matter) has shown the results of determined and more or less aggressive evaluation and development, even if it was "left up to Joe."

In the determination of chlorine it has become necessary to distinguish between the various forms of chlorine, and procedures for this have been developed. There are still several "catch-all" procedures included in the physical and chemical parameters. Perhaps the most outstanding are those for color, odor, and turbidity. In addition, silica might be included with phenol, organic and albuminoid nitrogen, and of course the organic carbon by BOD, COD, and chlorine demand.

TRACE ELEMENTS

Aside from the conventional and currently available methods of analysis, there is growing concern for information on heavy metal pollutants which, on adequate dilution of the gross pollution, still leave "trace" or significant concentrations of heavy metals as well as unknown biologically stable organics. This concern, as expressed by Gordon Fair, has grown as we move from the microbiological aspects of water supply to an age of microchemical aspects, because of the greater quantity and variety of pollution load carried by our streams and because of the greater knowledge that is being developed.

Certainly, there is need for better procedures for these parameters. The concentrations of interest may be such that one of the real problems will be concerned with the sorption or desorption of the metal ion from the sample container.

Interest has been shown by the U. S. Geological Survey in establishing procedures for the determination of these trace elements, but the results of their studies have not as yet been published. As another example, the finding that leaded gasoline is adding lead to water supply reservoirs where boating is permitted has stimulated interest in the determination of this element in such public water supplies.

Recently our laboratory requested the State Geological Survey to screen a sample of water from the Illinois River for trace elements by spectrochemical analysis. Copper was detectable in a concentration less than 0.1 mg/1; Mo and Cd less than 0.03 mg/1; and Pb, Ni, and Ti less than 0.01 mg/1. Sn, Co, Ag, Au, Zn, and Cr were not detectable. Higher concentrations were detectable in the suspended matter in almost every case - notably Pb between .013 and 0.13 mg/1. Except for lead, it would appear that further tests would yield unprofitable results; yet, this conclusion can be justifiably questioned.

USE OF DATA

Finally, we might ask ourselves of what use are the physical and chemical parameters aside from complying with standards of quality or ascertaining design criteria for the development and proper use of the resource.

The least that can be done is to publish a tabulation of the data alone or an intelligent summary of the data. Better yet, the publication can include the data in detail with an analysis and a useful summary for the reader. The summary should be presented in such a way that relationships, if any, can be drawn between different sets of data or for data from different locations, and generalities established which suggest a normal pattern exclusive of apparent unusual characteristics.

The unusual items or characteristics may then require further investigation to determine their source from a hydrologic, geologic, or pollutional standpoint. This is frequently the more interesting and challenging aspect of analyzing the data, and this effort is highly satisfying when deductions are confirmed by follow-up inspection with persistent investigation and perhaps special sampling.

Altogether too often, valuable data are never used or used only for a specific purpose and then discarded. The value of local or central agencies as a repository for records cannot be overemphasized. Such data must of course be well documented as to time and place. There are a number of commercial laboratories, for instance, that have vast records of partial analyses of untreated waters submitted from all over the country. Unfortunately such records are of very little assistance because of the absence of specificity on sampling.

CONCLUSIONS

In conclusion, it is impractical to make determinations for all possible physical and chemical parameters in all samples. Examination for such water quality requirements as are pertinent must be the minimum requirement. These examinations must be made to the necessary accuracy in the most efficient manner.

Essential prerequisites for every sample are representativeness and the inclusion of a proper sampling record as to time and place, etc. For programmed sampling schedule, some degree of flexibility should be permissible and periodic evaluations for adequacy should be made. The best sampling programs are those that recognize the cost of sampling and the value of adequate records, and that includes design for recognized multiple purposes for the data, when practical.

The assembly and analysis of the data for permanent records are essential for maximum use of the inherent costly but necessary programs.

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AQUATIC ORGANISMS*

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The quality of water until relatively recent times was of interest only to the person drinking it. Today usable water quality is of concern to the person drinking it, and using it for his domestic animals; to health authorities who fear high nitrates or pathogens; to the health physicist who fears possible radioactivity; to the chemist who looks at possible dissolved toxins or poisons; to fish culturists who wish to raise fish for selling or stocking; and to water authorities who wish to assure householders and industrial users that it is not excessively hard or soft, high in iron, high in sulfur or salts, and a myriad of other specifications. This adds up to all sorts of parameters as measurements of the usefulness of a given water. This discussion will look at some of the biological parameters.

DEAD ORGANISM REMAINS

There are many ways in which the biota of water affect its quality. One thinks immediately of living organisms, but the remains of once living organisms need just as much consideration, especially recent remains. Thus last year's cypress leaves, plus those accumulated in past time so soften and color the water of certain lakes in Florida as to detract from them as places to swim, and use for household purposes, as well as to make them less preferred for bass and pan fish fishing. It must be admitted that familiarity eventually breeds contempt for these conditions however. Tupelo gum leaves blacken the swamp waters in which the trees live, and inhibit the development of certain plants and animals until these swamps become a specialized environment. Hoak (6) has shown that oak leaves contribute significant amounts of phenolic compounds to certain Ohio valley waters. The effects of dead animal bodies hardly need mention.

PLANTS GROWING IN WATER

Plants growing in water also may affect quality, directly or indirectly. This idea may seem far fetched but one must remember that water quality parameters may be aesthetic, biological, chemical or physical. In the late twenties and early thirties the TVA lake construction program had to meet certain reservoir clearance specifications set up by the States served. These intended to prevent decay of existing vegetation, and growth of new, as from sprouting, once the area was submerged. The actual purpose was to cut down breeding of Anopheles quadrimaculatus, the malarial mosquito, among debris and aquatic plants. It may be argued that this is no consequence of water quality, but the sanitary engineer charged with prevention of mosquito breeding, or the industrialist who has to screen and filter such water would be inclined to regard vegetation and debris choked water as a physical characteristic.

Some southern states, notably Louisiana, annually spend millions of dollars to control water hyacinth, Eichornia crassipes. The only actual effect of this plant on the underlying water is to cut off light and to exhaust nitrates and phosphates. Secondary effects are to lower DO values and to prevent the growth of phytoplankton. These in turn affect fish production. There is no particular sanitary quality involved, but certainly useful qualities are. Water Milfoil and Elodea (Ceratophyllum spp and Elodea spp) often make the newspapers when some sportsman's group wants them eliminated from a body of water in the interest of better fishing and boating. A large sign on the boat berthing and landing dock in Narrow River in Rhode Island asked residents of the new development to sign the petition in July, 1960, to eliminate the pollution by eel grass. Actually the river (salt) was over fertile and produced excessive growths of Zostera which interfered with boating, bathing, fishing and crabbing. The coliform count for the water was satisfactory.

Such instances could be multiplied indefinitely, but a final one will suffice to show we are dealing with organism-induced effects on

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water quality. *Tilapia* is a valuable food fish in certain tropical waters. It feeds on plankton, and in Lake Victoria in Africa a low plankton content was believed the cause of a small *Tilapia* population. Hesse (5) found that the low SO_4 content limited plankton production; he studied sulfur distribution in mud, water and vegetation, and found that when the plankton contained only 0.017 ppm Water Lettuce (*Pistia*) contained 3.060 ppm. The quality of the water, insofar as plankton production was concerned was impaired by the *Pistia*.

POTABLE WATER MICROORGANISM STANDARDS

Primarily it must be supposed we are interested in water used by man more directly, e.g., potable water for ourselves and our animals, and such water as we farm. What are the measurements of a good water for such purposes as these? Chemical and bacterial standards are fairly well drawn up, but there are few actual standards relative to the numbers of non-bacterial organisms in the water we drink. Probably it is taken for granted that if the bacterial standards are met, other organisms will have been eliminated. There is also the unexpressed standard that a person will not drink water containing visible living organism. Both these are fallacies. Table 1 shows the results of examining water samples taken according to a well dispersed pattern, from the distribution system of a modern Florida city. This water, from deep wells, presumably had been sufficiently chlorinated so that its coliform index was low; certainly it was satisfactory to the State Board of Health. It was also satisfactory as to taste, odor and color. There had been some complaints about "worms" in the drinking water. On flushing a fire hydrant there was at times an initial surge of muddy water, but this is usual. However, tap drawn samples often showed small foreign bodies, occasionally self propelled, and occasionally recognized as "worms". In centrifuging only 100 mls of each of the 12 samples at 2200 rpm for five minutes, the above 31 kinds of organisms were recovered. This indicates a very sizeable population of what might be termed "stagnant water biota" in the system, and it indicates enough organic matter in the system to create a sizeable chlorine demand. Also there are some organisms which might release living *E. coli*, *E. typhosa* and *Salmonella* if the chlorination system should break down.

With Table 1 in mind, it might be a good idea to set some standards as to non-bacterial organisms. Molds are easily recoverable from many potable waters and this Florida city is not alone in providing in its drinking water as one sanitary engineer said "More protein". Most people at least want their protein cooked. Entirely aside from the psychological and possible public health aspects of such organisms in potable water, one suspects that such a condition is near or beyond the danger point for bacteria, perhaps other than *E. coli*. Filtration is not the answer - the animals must be killed. Complete filtration removes most of the living organisms in water and is sufficient in the case of many industrial waters. It may result, however, in raising the organic content of water if the raw water contains large volumes of living organisms which are killed by the filtration process. Organic matter, whether living or dead, in some such waters is bad. Consider an operation requiring a high permissible passage of light through the water in use. Beers' law says the percentage of incident light absorbed increases exponentially with the concentration of light absorbing material present. Only very careful filtration can remove such colloids as result from killing and cytolysis of living organisms. Deep waters low in living organisms often show an intense blue color because the other spectral colors are filtered out at shallow depths, the blue being the one last extinguished. Lake Tahoe is an example.

If a near absence of living organisms is desirable for potable and industrial water, what about the waters we farm? We are prone to forget that some foods are raised in water. Watercress is an example. The water should be hard (limestone), cool to cold, and free of pathogens. It is not feasible to sterilize such water, but Watercress from a polluted stream is dangerous, simply because its stems below water (the plant is an emergent aquatic) usually develop mixed growths as the stems grow older. These "aufwuchs" may easily contain pathogens. Meat crops in the form of shellfish, fish and crustaceans especially need clean water; shellfish specifically because they, like Watercress, are eaten raw. Closing of shellfish beds because of sewage pollution is an old story, and the general measuring stick is the

Table 1. EXAMINATION OF SAMPLES FROM A CITY DISTRIBUTION SYSTEM

Key to columns:
1. Fire hydrant
2. Well, Ball Park
3. Fire Hydrant
4. Fire Hydrant, near sulfur well
5. Well
6. Blow off tap
7. Well supplying elevated tank
8. Elevated Tank
9. County supply
10. Fire plug
11. Fire plug
12. Fire plug

	1	2	3	4	5	6	7	8	9	10	11	12
Deposit, $Fe(OH)_2$	X		X			X		X		X	X	X
Deposit, FeS				X	X	X		X				
Rotifera	X					X				X	X	X
Nematoda	X		X	X		X			X	X	X	X
Ostracoda			X	X		X		X			X	X
Tardigrada			X									
Annelida											X	X
Zooglea ramigera				X		X						
Beggiatoa alba											X	X
Beggiatoa leptomitif.												
Thiothrix				X	X	X	X				X	X
Sphaerotilus						X						
Leptothrix	X											
Gallionella	X					X				X	X	X
Arcella				X						X	X	X
Centropyxis	X		X	X		X				X	X	X
Difflugiella			X	X								
Euglypha			X	X		X		X		X	X	X
Pelomyxa						X						
Unid. small flagellates			X	X		X	X	X		X	X	X
Bodo						X						
Entosiphon										X		X
Oicomonas			X					X			X	X
Menoidium										X		X
Peranema			X					X		X		X
Unid. ciliates										X		
Aspidisca			X									
Chilodonella			X	X								
Cyclidium				X								X
Drepanomonas			X			X						
Halteria								X				
Prorodon			X									
Tetrahymena			X			X						X

coliform index. Here also - in salt water - it is possible we need other indices as to the quality of water. For one thing, the shellfish industry is still searching for water characteristics which will insure an annual crop. And part of this program is knowledge of the biota in shellfish producing areas. The U. S. Fish and Wildlife Service in the past few years has become actively interested in the biotic characteristics of water in which various fish and shrimp are produced.

POLLUTION RELATIVE TO USEFUL PRODUCTION

Another study currently underway in California, is seeking to assay the optimum environment for the successful maintenance and cropping of the giant kelp, Macrocystis pyrifera. This plant has great economic value to the Pacific coast and there was some indication that sewage pollution endangered the beds in a few areas. A detailed survey of the microbiota of San Diego harbor and adjacent waters in the summer of 1959 failed to show marked differences attributable to sewage and industrial wastes as one moved out of the harbor, and it is evident the matter needs more study over a longer period. There have been far too few studies of the microbiota-pollution relationship in marine waters. Even when a clear relationship between pollution and organism content has been established, as in Great South Bay, Long Island, the underlying causes of the microbiotic changes have not been found. They could be dominance, due to an optimum environment for certain species, or antibiotic production. The Town of Islip, largely because of the active promotion of a shellfish producer, George Valderborgh and Son, is supporting these studies on a yearly basis, but more correlation betweenfield and laboratory studies is needed. Nevertheless, workers are able to say definitely that continued large numbers of certain plankton organisms means a deterioration of quality or production or both, of Blue Point oysters. This represents a long step forward, even if the basic conditions and causes are yet to be discovered.

WATER CHARACTERISTICS INDICATED BY BIOTA

Looking again at potable water, its qualities are affected by kinds of organisms present in the raw water, and by numbers. We think of toxicity, taste, odor, color, filterability, O_2 removal and BOD as directly affected by biotas. Toxicity is rarely a quality. However, there is a large literature on toxicity of raw water containing large quantities of blue green algae, usually Microcystis. The literature is in some disagreement on the mechanism and there is a decided lack of carefully controlled experimental work. It should be experimentally decided whether such toxicity is transmissable through the usual water purification processes.

There is also a large literature on taste and odor, including the organisms incriminated, and the treatments. This matter has reached the point where many water purification systems regularly sample their raw waters to note the onset of various organisms, upon which some method of restriction such as $CuSO_4$ is used.

There is much less known about biological agents causing color, except tannic and humic acids previously mentioned, but there are fewer instances of this reported. The same is true of kinds of organisms causing filter clogging and the numbers in raw water which cause a shortening of filter runs. A water plant superintendent could perform a real service to the profession by collaborating with a biologist in establishing a list and giving numbers, relative to this trouble.

Oxygen removal and BOD increase are primarily functions of organism numbers in raw water. There are no indicator species for either. Large numbers of chlorophyll containers may produce O_2 supersaturation, but they decrease light penetration and in darkness are oxygen users. Colorless species of course remove oxygen at rates depending on their numbers and activity, and all species tend to create an oxygen demand on dying. One factor not generally understood is that many chlorophyll containers are only partly autotrophic; they do not function fully in photosynthesis. Lewin and Lewin (9) have found this true of several species of diatoms, and at the Narragansett Marine Laboratory in the summer of 1960, at least four diatom species were active in the sand four to six inches below the surface. They contained no visible chlorophyll.

However this very attribute of partial heterotropism may enable various species of Euglena to thrive in anaerobic and polluted habitats. Thereby they hasten recovery of the water to a completely oxidized state. There are a number of genera and species characteristic of such environments, but Euglenophyceae and Volvocales are most abundant in the plankton and certain diatoms in the benthos.

There are also organisms in the benthos which tell much about the quality of water at the bottom. Chemically, one simply measures the DO. If there is none, the bottom waters are anaerobic. But this does not tell very much about the water. It may contain H_2S in small or large amounts; or methane; be acid or alkaline; or be fresh or salt. The salt may be a bottom layer of dissolved magnesium sulfate instead of sodium chloride as Anderson (1) has found for a lake in Washington. The water may overlie a rich organic layer. Much can be determined about this area from the biota. We have long known that a relatively small group of protozoa exists in anaerobic depths. Most of them are benthic, but not all. If a water sample shows Ctenostomata (Epalxis, Saprodinum, Discomorpha and their relatives); Metopus; and colorless flagellates such as Tetramitus and Trepomonas, the water is certainly anaerobic and contains some organic matter, at least enough to provide a bacterial population whose size is indicated by the protozoan population. Bick (2, 3) in two recent papers discusses the occurrence of various organisms in polluted fresh water and the mud water interface. Of importance to this presentation is the fairly complete listing he gives, for the conditions shown. In these waters he dealt with a pH always above 7.0, a condition which generally produces good growths of the sulfur bacterium Beggiatoa. Beggiatoa is generally supposed to indicate pollution and anaerobiosis, if present in quantity but recent studies (8) indicate it simply shows the presence of H_2S, and may be abundant irrespective of the above two factors.

Acid waters however show a great decrease in the numbers of protozoa when the water is polluted. In fact, experience indicates there are so few protozoa as to make them useless in the indicator sense. Table 2 lists the algae and protozoa which reasonably delineate organically polluted waters or those naturally devoid of O_2, such as sulfur springs. There is no point in listing the microbiota of unpolluted waters, either fresh or salt. For these, the biota is large in numbers, and varied in kind, even in waters containing quite small amounts of PO_4 and NO_3. Neither is there any reason to list those organisms which tolerate wide ranges of environmental conditions, so that they occur, even abundantly, in both clean and polluted water. It is probable for example that there are species of Cyclidium and Euplotes which occur in good water, and others which occur in bad, but it might require a cytological examination to distinguish them. It will be noted that there are very few green forms in Table 2. Grossly polluted waters are generally turbid, and as green forms require light, they are generally excluded by the environment. This is one reason why no blue green algae are listed. At the same time a table such as this could readily list the sulfur purple bacteria, the Beggiatoales and a few other sulfur bacteria. Considering that gross pollution is severely restrictive in many ways, it seems remarkable that Table 2 lists as many organisms as it includes.

All the species listed in Table 2 occur in water which is pH 7.0 or above as a rule. If they occur in acid water their occurrence is apt to be very sparing. Some of the Ctenostomata and Metopus have been found a few times at pH 6.5. The sole organism which has been found only in an acid water has been a bottom dwelling Pelomyxa, but some colorless Euglenephyceae may be peculiar to such situations. It will be stated that Table 2 is not inclusive, and it is not claimed to be. But it is based on experience in a field which needs much more investigation so that eventually it may be far more inclusive than it now is. Liebmann (10) has a lengthy treatment of the subject matter of Table 2, and he too was on the conservative side.

A separate table could be made for the organisms peculiar to water containing H_2S. This water is not necessarily polluted (by man) but is difficult to use for potable water by individuals although H_2S is easily removed by treatment. Such water, whether fresh or salt, contains a characteristic group, some of which are found in Table 2. In a Symposium at the Taft Center in 1957, (7) 110 algae and protozoa were listed as to their oxygen relationships and their occurrence in fertilized or polluted waters. At first sight some of them appear not to agree with their listing here in

Table 2. ALGAE AND PROTOZOA WHICH INDICATE ORGANIC POLLUTION OR ANAEROBIC CONDITIONS BECAUSE THEY ARE PECULIAR TO SUCH SITUATIONS OR BECAUSE THEY ATTAIN LARGE NUMBERS THEREIN.

F.W. = Fresh Water; M = Marine

Polytoma uvella F.W.
Spondylomorum quaternarium F.W.
Pyrobotrys gracilis F.W.
Trentonia flagellata M
Hemidinium sp. M
Euglena agilis F.W.
Euglena pisciformis F.W.
Astasia sp. F.W., M
Navicula cryptocephala F.W.
Mastigamoeba sp. F.W., M
Mastigella sp. F.W., M
Cercobodo sp. F.W., M
Helkesimastix faeciola F.W.
Phanerobia pelophila F.W., M
Gyromonas ambulans F.W.
Hexamitus inflata F.W.
Trigonomonas compressa F.W.
Trepomonas spp. F.W., M
Urophagus rostratus F.W.
Tetramitus pyriformis F.W., M
Ctenostomata, all species F.W., M
Caenomorpha medusula F.W.
Dexiotrichides centralis F.W.
Chaenea spp. F.W., M
Enchelyomorpha vermicularis F.W.
Gastronauta spp. F.W., M
Geleia sp. F.W., M
Dexotricha caudatus F.W.
Glaucoma pyriformis F.W.
Lagynus elegans F.W.
Lagynurus pumilio F.W.
Lembus infusionum M
Loxodes vorax M
Ludio parvulus F.W.
Metopus spp. F.W., M
Paramecium putrinum F.W.
Protocrucia pigerrima M
Spirostomum spp. F.W., M
Strombidium spp. F.W., M
Tillina magna F.W.
Trachelocerca coluber M
Trimyema compressa F.W.
Tropidoatractus acuminatus F.W.
Urocentrum turbo F.W.
Uroleptus spp. M
Urotricha farcta F.W.
Urozona butschlii F.W.

Table 2, but such is not the case. Actually we may judge very little about the condition of a water from a single species, a great deal by the combined species in that water.

SOME WATER QUALITIES NOT CHARACTERIZED BY BIOTA

The above statement has some striking exceptions to a strict interpretation. Two instances will serve. Chlorination of water to kill microorganisms is routine. In experimental work on the use of chlorine and iodine to keep swimming pools free of algae, we have, during the past two years accumulated a list of some fifteen organisms, mostly algae, which resist chlorine and iodine dosages far beyond the dosages tolerable to swimmers. One might look at a pool with "black and brown" algae in it in such numbers as to discourage use, and conclude that the treatment mechanism had failed. Actually strains of Anabaena and Navicula might be present which were highly resistant.

The microbiota in water yield no information either in regard to the radioactivity of the water. Algae and protozoa simply fail to distinguish, to our senses at least, between radioactive isotopes and stable isotopes. Two years of experimentation have shown that a very large number of species (all we have tried) grow as well in media containing radioisotopes as those containing stable isotopes. They may accumulate a given one many hundred or thousand fold what it is in the environment, but with no apparent effect. And they resist enormous dosages of gamma radiation. In such cases they have no yardstick value whatever.

ADEQUATE SAMPLING

Attempts to evaluate water quality from a knowledge of its contained microbiota are useless unless the worker knows the body of water in question is adequately sampled. Plankton are notoriously inclined to be patchy, a fact probably appreciated by any field worker. Yet the chemical nature of the water in a dense patch of plankton probably is not detectably different from plankton poor water half a mile away. One has but to fly over Peconic Bay, Long Island, at a time when certain dinoflagellates are in bloom to be dramatically impressed by this patchy distribution. Hardy (4) was quite impressed by such uneven distribution in the open tropic and antarctic oceans. Even in ponds such patchy distributions are observable. Some of this may be due to wind, some to unexplained causes. In July 1960, a red patch of considerable size was observed moving into a small cove in front of the Narragansett Marine Laboratory. There was a slight breeze and to some extent the patch moved with it, but the patch maintained its integrity. A liter beaker was dipped into it, and was filled at once by a crowded mass of a marine jellyfish, a "comb jelly", Mnemiopsis leidyi. Other plankton in the area were virtually nonexistant, although further out from the patch there was a fair amount of microorganisms. An adult comb jelly is about an inch or more long, about three fourths that in diameter. The chances of getting one per liter by a casual dip in Narragansett Bay were undoubtedly remote, yet this dip secured literally a liter of them.

The same patchiness applies also to bottom sampling. In the same laboratory several observations weekly were made on about 20 locations in five wooden aquaria. These were 18 x 12 x 12 inches and had been filled with bottom sediment to within an inch of the top some months previously. A gentle flow of ocean water was maintained across their top, enough to provide a constant fresh supply, and dissolved oxygen, but not enough to disturb the mud-water interface. At a number of places along the sides, patches of white sulfur bacteria grew, and these changed almost not at all during six weeks.

These patches contained a constant microbiota which differed in quantity and quality from a point perhaps six inches away. The data on these is being presented elsewhere, but the differences in space, and the constancy of organism occurrence at a given point were quite striking. It would appear that a sampler must know how he is going to secure what amounts to a representative sample of the water under study, and that it is no cut and dried matter.

SUMMARY

It appears then, that the presence or absence of microorganisms in a water may indicate nothing about the qualities of that water, or they may indicate a great deal.

A very low organism content may be due to a lack of growth promoting substances, from the necessary elements to vitamins. Or it may be due to lack of oxygen, the presence of toxins such as antibiotics (which rarely apply to more than a few species, however) or to no aging of the water, or to temperatures which depress the division rate.

The kinds of organisms may indicate an H_2S content or sea salt, or fresh water or other characteristics. There are few individual species which of themselves are meaningful. But there are associations which mean a great deal. There is of course much overlapping of species from one environment to another and some species tolerate such a wide range of environment as to be ubiquitous, and as species, meaningless. But they may reproduce very rapidly in one environment and slowly in variations from this, and hence be useful in this respect. There are environmental factors also which appear to be inocuous insofar as organisms are concerned. Radioactivity is one of these, although X-rays behave differently.

High numbers of organisms in a given volume of water are generally significant of a high nutritive level. A review of the literature will show that large numbers of certain organisms are often significant. *Polytoma uvella* in large numbers generally indicates starchy wastes; mixed Euglenophyceae, recent fecal pollution, most often from barnyards or cattle droppings; *Euglena pisciformis*, *E. agilis*, *E. acus* and *E. viridis* in large numbers, domestic sewage; *Gonyostomum semen* and *Euglena velata* or *E. polymorpha*, acid cedar or cypress water. These are not finite statements but they are certainly strong trends and within a short time we should see them in the literature as tabular material. A final word of caution is necessary however; one must be sure: (a) that representative and adequate sampling is carried out, and (b) that the biological findings are backed by adequate chemical and physical tests. Determination of water quality, for whatever use, is no longer a simple matter.

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BACTERIAL PARAMETERS OF WATER QUALITY

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After it was demonstrated by the work of Eberth in 1880, and Koch in 1884, that Salmonella typhosa and Vibrio cholera were associated with intestinal disorders, several procedures were developed for the recovery of these and other etiological agents of human disease from water. Although specific pathogenic bacteria have been isolated from polluted water many times, such attempts almost always have ended in failure when used as a routine test for water quality. Such examinations are, therefore, not recommended because available methods are tedious, laborious and require high technical skill and because the time for remedial action is past long before the pathogen is identified.

Following Escherich's (1885) findings that Escherichia coli was a normally occurring intestinal organism, other investigators showed that E. coli, as well as several related organisms (coliforms) were consistently present in sewage, polluted waters and in contaminated soil. Because the coliform group is constantly present in alimentary discharges, and because of the comparative ease of enumerating them, the coliform organisms have become accepted indicators of fecal pollution. Due to the fact that water containing organisms indicative of fecal pollution may also contain enteric pathogens, the results of the "coliform test" have become important considerations in judging the sanitary quality of water.

COLIFORM GROUP

The coliform group is defined in standard Methods for the Examination of Water and Waste Water, 11th ed. (1) as follows: "The coliform group shall include all of the aerobic and facultative anaerobic Gram-negative nonsporeforming bacilli which ferment lactose with gas formation within 48 hours at 35°C." This definition includes organisms which differ in biochemical and serological characteristics and in their natural sources and habitats such as E. coli, Aerobacter aerogenes, E. fruendii, and other intermediate forms, as well as certain Erwinia, Serrateae, etc. The definition is, therefore, in terms of a performance test under prescribed conditions and this group definition should not be confused with single species descriptions as found in textbooks of bacteriology.

E. coli is characteristically an inhabitant of the human and animal intestine (2,3,4,5). A. aerogenes and A. cloacae frequently are found on divers types of vegetation (6,7,8), and in materials used for packing joints and valves of pumps and pipelines, (9, 10). The intermediate-aerogenes-cloacae (I.A.C.) subgroups are found in fecal discharges, usually in smaller numbers than E. coli. A. aerogenes and intermediate types are commonly present in soils (11,12,13) and in water polluted sometime in the past. Another subgroup includes plant pathogens (14) and other organisms of indefinite taxonomy about whose habitat information is limited. All of the subgroups may be found in sewage and in polluted waters.

Available laboratory procedures do not differentiate between coliforms from animal and human sources; however, because many domestic and wild animals discharge organisms in their feces and urine which are infectious to humans, differentiation of coliform source is of little importance. Contamination from either type of waste renders the water potentially unsatisfactory and of unsafe sanitary quality. The coliform group have therefore been traditionally considered "indicator" organisms of pollution because:

a) They are normal inhabitants of feces.

b) Large numbers are present in sewage and in waters polluted with sewage.

c) They indicate zones of fecal pollution in waters.

d) They are relatively easy to detect by routine procedures.

e) While usually harmless in themselves, they indicate the potential presence of disease producing enteric bacteria.

The first coliform test was developed at the New York State Department of Health Laboratories by Theobald Smith in 1893 (15). Standard Methods of Water Analysis was first published in 1905 and have been revised and improved through the years. The eleventh edition, 1960, has some recognized imperfections in methods as to time required, specificity and reproducibility. However, continuous improvements have been made in methodology such as:

a) Substitution of lactose for glucose in the presumptive medium, which materially reduced the number of presumptive false positive tests.

b) Churchman's observation that some dyes selectively inhibit certain species or groups of Gram-positive and of spore-forming organisms.

c) Modifications of media, as use of bile salts by MacConkey in 1908 (16), brilliant green bile medium by McCrady in 1937 (17), and lauryl sulphate tryptose broth by Mallmann in 1941 (18).

d) Development of the membrane filter procedure (1,19,20,21) which uses new equipment, materials and incubation times.

In treated drinking water, the presence of any coliform type suggests either inadequate treatment or access of undesirable materials to the water after treatment. Recognizing that there are some subgroup and strain differences in survival under natural conditions and resistance to chlorination, in general, all the coliform organisms exhibit survival and resistance patterns in the same order of magnitude. Insofar as bacterial pathogens are concerned, the coliform group is considered a reliable indicator of the adequacy of treatment. As an indicator of pollution in drinking water supply systems and indirectly as an indicator of protection provided, the coliform group is preferred over the fecal coliforms (E. coli).

FECAL COLIFORMS

Because all members of the coliform group normally occur in diverse natural habitats (2 to 13), attempts have been made to differentiate the population in polluted waters according to their original sources. The first of these procedures was described by Eijkman in 1904 (22) who proposed a "fecal coli" test that he believed distinguished coliforms from the gut of warm-blooded animals from strains originating in cold-blooded animals. The method presumed that only fecal types of coliforms from warm-blooded animals could grow in glucose broth at 46°C with the production of gas. About the same time, MacConkey (23,24) defined the aerogenes subgroup in terms of certain fermentation characteristics, inability to produce indole and positive reaction in the Voges-Proskauer test. Rogers, Clark and Davis (25), Koser (26), Clark and Lubs (27) and others developed laboratory techniques and data which differentiated the coliform group on the basis of indole production, methyl red and Voges-Proskauer reactions and citrate utilization (IMViC tests) into the E. coli, aerogenes, intermediate and irregular subgroups. More recently, Hajna and Perry (28) and Vaughn, Levine and Smith (29) have further developed the Eijkman test to distinguish organisms of fecal from nonfecal origin by increased temperature incubation. Clark et al. (30, 31) have reported additional data which indicate that the ability to produce gas under increased temperature incubation yields a higher correlation with fecal source than does differentiation by the IMViC reaction. E. coli is therefore frequently referred to as "fecal coli" and the intermediate-aerogenes-cloacae subgroups as "nonfecal". However, it must be remembered that these terms are only relative and that the term "fecal coliform" is used in this report to designate those organisms which ferment lactose with the production of gas at 45°C and is somewhat more inclusive than the IMViC type 1. E. coli.

Current information indicates that members of the I.A.C. subgroups tend to survive longer in water than fecal coliforms (32,33,34). The I.A.C. subgroups also tend to be slightly more resistant to chlorination than E. coli or the commonly occuring intestinal pathogens (35,36,37,38). Because of these and other reasons, the relative survival of the coliform subgroups may be useful in distinguishing recent from remote pollution. In waters recently contaminated with sewage, it is expected that organisms of the fecal coliform subgroup will be present in greater numbers than those of the I.A.C. subgroups. However, in waters that have been contaminated a considerable time previously or insufficiently chlorinated, organisms of the I.A.C. subgroups may be more numerous than fecal coliforms.

In relation, therefore, to the sanitary significance of the various coliform subgroups in untreated waters, fecal coliforms may be considered an indicator of recent fecal pollution. And because fecal pollution of both human and animal origin may contain bacteria pathogenic for man, it is necessary to consider all fecal coliforms as indicative of dangerous contamination. In the absence of fecal coliforms, the presence of I.A.C. subgroup organisms may be due to relatively remote fecal pollution, to decaying vegetable matter, to soil "runoff" water, or infrequently to fecal pollution containing only the I.A.C. subgroups.

FECAL STREPTOCOCCI

Although the significance of the streptococci as sewage organisms is not established on as definite information as is our knowledge of the coliform group, the streptococci have been isolated so frequently from polluted sources and so rarely from uncontaminated waters that it seems reasonable to regard their presence as indicative of pollution. Sewage streptococci were first observed by Laws and Andrewes in 1894 (39) and their importance described by Houston in 1899 and 1900 (40) when he reported that they were, "readily demonstrable in waters recently polluted and seemingly altogether absent from waters above suspicion of contamination." In this country, the sewage streptococci were first reported by Winslow and Hunnewell in 1902 (41).

In 1937, Sherman (42) reviewed the information on streptococci, and suggested the enterococcus group containing Streptococcus faecalis, S. liquefaciens, S. zymogenes and S. durans as indicator organisms of fecal pollution. Technical improvements in enumerative methods were described by Winter and Sandholzer in 1946 (43), Hajna in 1951 (44), Litsky et al. in 1953 (45) and Slanetz and Bartley in 1957(46).

Undue emphasis has been placed on the enterococci (S. faecalis group) with little or no consideration for other streptococcal strains present in the gut of humans or other warm-blooded animals or birds. That the predominant species of streptococci may vary markedly in different animal excreta has been suggested by Barnes et al. (47), Cooper and Ramadan (48) and Feivins et al. (49). Kenner et al. (50) found in an extensive survey of fecal samples from the Cincinnati area that the enterococcus group when used as indicators of fecal pollution, represented only 77 per cent of the total streptococci present in human pollution, 25 per cent for sheep, 12 per cent for cows and 10 per cent for pigs. Quadruped excreta showed appreciable quantities of S. bovis and S. equinus which amounted to approximately 75 per cent for cows, 46 per cent for sheep and 56 per cent for pigs. The use of fecal streptococci as indicators of fecal pollution was therefore recommended. The fecal streptococcus group includes the enterococcus group, S. mitis-salivarius group, S. bovis, S. equinus and an atypical group closely resembling the enterococcus group but with one or more differences in critical biochemical tests.

Fecal streptococci appear to be characteristic of fecal pollution, being consistently present in feces of all warm-blooded animals and in the environment associated with animal discharges. They do not multiply in streams or other surface waters to produce overgrowths as sometimes occurs with the coliform group. So far as is currently known, they rarely occur in soil or on vegetation not subject to continued sewage pollution. Therefore, the presence of fecal streptococci in water indicates fecal pollution in amounts no greater than originally present or in some instances in reduced amounts comparable to the combined effects of natural purification processes.

SUMMARY

1. As an indicator of pollution in drinking water supply systems and indirectly as an indicator of protection provided, the coliform group is preferred over the fecal coliforms (E. coli).

2. In untreated waters, the presence of fecal coliforms indicates recent and possibly dangerous pollution. In the absence of fecal coliforms, the presence of intermediate-aerogenes-cloacae organisms suggests less recent pollution or soil "runoff".

3. The presence of fecal streptococci in raw waters indicates relatively recent fecal pollution. On the basis of species distribution, rough estimates of human versus animal pollution sources can be made.

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DETECTION AND MEASUREMENT OF ORGANIC CHEMICALS IN WATER AND WASTE

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WHY MEASURE ORGANIC CONTAMINANTS IN WATER?

It is well to review occasionally our reasons for making chemical examinations in connection with water quality or else we may become engrossed in refinements of technique and pursue these instead of concerning ourselves with what useful information the test is yielding. Or, we may succumb to the temptation to run the time-honored tests because we know how to do them so well and because they have been around so long it just doesn't seem proper to drop them. Let us examine the tests we run on organic contaminants in water and ask whether we have justifiable reasons for making them. At the same time we will try to assess the adequacy of our procedures for describing the organic contaminants.

Historically, the sanitary engineer has focused his attention on the dissolved oxygen in a stream. The BOD test, which measures organic matter subject to aerobic decomposition, has been in use over half a century. The COD test measures a larger segment of the organic matter, but essentially only the carbonaceous materials are measured efficiently. While these tests are useful as measures of oxygen-demanding power of wastes, they tell nothing of composition and they do not measure all of the organic matter.

Organic nitrogen as measured by the Kjeldahl method enables the scientist to estimate proteins and intermediate decomposition products. This test when used with other tests for the various forms of nitrogen provides helpful information on the stage of pollution in the stream.

Phenolic compounds received much attention from analysts early in the history of industrial pollution. These materials, at very low concentrations, increase in taste and odor intensity and objectionableness upon chlorination. This unique property forced the development of sensitive analytical procedures for phenolic materials.

Other tests for organics in Standard Methods include a test for tannins and lignins, oil and grease, and in the case of sewage, tests for volatile solids and volatile acids. Many other tests for organics exist but they have not been used commonly enough to become standard procedures.

NEW PROBLEMS

Following World War II a definite upsurge in incidents associated with organic contaminants in water occurred. Tastes and odors in drinking water were reported more often and the events seemed more severe than earlier episodes. Fish kills believed to be caused by organic insecticides were reported, but quite often the exact cause could not be found. Commercial and sport fishermen complained of off-tastes in fish caught in certain area. Algae bloomed in unusual profusion where sewage effluents furnished necessary amounts of nitrogen and phosphorous. Water plants reported occasional unexplained difficulties with coagulation and color removal. Foam appeared on some waters when drawn from the tap. On other waters, it was not possible to apply enough chlorine to get a breakpoint. Ion exchange beds failed prematurely on some waters.

Our demands for exceptionally pure water have increased. Parts per billion concentrations of contaminants are important. Public demand has required that we have better water than was acceptable in former years.

When the chemist sought to measure possible contaminants doing the damage, methods were often lacking. Some way of testing for contaminants can usually be found (it is seldom easy) if the urgency is real.

FINDING THE CAUSE OF DAMAGE

Let us follow through the various steps taken to find the cause of foaming in water. The presence of foam at sewage plants, particularly when aeration is a part of the process, leads one to look at what goes into the sewer that may cause the difficulty. Components which have been common to sewage for many years can cause foam. But, a new and widely used foaming material has been added to sewage in increasing amounts over the past 25 years. Anionic synthetic detergents containing alkylbenzene-sulfonate (ABS) as the surfactant provide this troublesome new additive. It has high foaming capacity even at levels of only 1 ppm. The chemist found that he did not have a suitable analytical procedure to measure ABS. Methods soon began to be published. The most common procedure is based on forming a complex of the ABS and methylene blue followed by extraction with an organic solvent and comparison with standards on the spectrophotometer. In the early work, no uniform standard was available. Close examination of the methylene blue test revealed some defects (although it is still a very useful test) and a committee of the American Soap and Glycerine Producers Association set about to develop a more definite procedure. A suitable standard was developed and made available. An infrared method was developed for measuring ABS after several thousand man-hours were spent on it. Even this procedure has faults for routine use. It is too long and difficult and better short procedures are being sought.

By having sensitive and accurate procedures for measuring ABS and on finding the materials in situations where foam is occurring, it is reasonable to believe that the material is an important contributor to the condition. On the other hand, you cannot say, in the absence of tests, that all foams are caused by ABS. These procedures do not measure non-ionic detergents which are also a component of sewage. These compounds may have to receive an analytical flailing equal to that given ABS to establish reliable estimates of their concentrations.

When the water utility operator asks, "What is causing the taste and odor in my drinking water?" it is a legitimate -- and difficult question. The chances are that the cause is an organic material. It may have originated as a natural phenomenon, organisms may have produced it, or industrial or domestic wastes may have been important contributors. More often than not, the taste and odor results from a complex of pollutants and the amounts of some materials that can be detected by odor are fantastically small being in the range of a few micrograms per liter.

HOW DOES THE CHEMIST TRY TO ANSWER THE UTILITY OPERATOR'S QUERY?

The first and most simple procedure is to run a threshold and qualitative odor or taste tests. These give some information as to the intensity and type of odor and serve to guide the chemist but will seldom be sufficient alone.

If phenols are suspected, direct tests can be made. Concentration may be achieved by distillation. Extraction of the distillate or even the water before distillation may serve as an additional concentrating mechanism. The object is to recover enough of the offending materials to test. Quite often distillation and extraction will not yield enough material for analysis.

To extend our ability to concentrate organics from dilute solution, activated carbon can be used. This material has phenomenal ability to adsorb organic materials. Unfortunately it does some selection and the carbon doggedly retains some substances or some portion of the adsorbed materials. Still the procedure yields information that is quite useful and the recovered materials can be seen and smelled. Defects in any procedure must be recognized in the interpretation of the results.

Details of the filter have been given elsewhere. Briefly, the organics in the water are adsorbed onto a bed of activated carbon contained in a tube 3 x 18 inches. Three to five thousand gallons of water are passed through the filter at a rate of 1/4 g.p.m. The carbon is dried and extracted with chloroform. The chloroform is distilled off and the residue remaining is called the carbon chloroform extract. The carbon is next extracted with alcohol and the recovered residue is the carbon alcohol extract. Other treatment will yield still further materials, but the process is usually stopped after the chloroform and alcohol extractions.

The chloroform extract is of most interest in revealing taste-and odor-bearing materials, petrochemicals, and insecticides. The alcohol solubles appear to be water-soluble oxidized products which for lack of a better name we call humic materials. The chloroform solubles are separated by taking advantage of solubility differences. Column chromatography of the neutral group and infrared tests on selected fractions constitute the usual tests. There are many more approaches to the examination of the extracts. A recent and powerful technique involves steam distillation of the chloroform extract, followed by group separation, then further separation by gas chromatography with collection of the samples from the outlet. Infrared examination of these fractions may identify the materials. The extent of analysis depends on what is sought.

WHAT ARE THE AREAS OF USE FOR THE CARBON TECHNIQUE?

One use of the carbon technique is to monitor the organic content of drinking water. Here, the organic load should be least. It is rare to apply such tests as BOD and COD to drinking waters because the tests do not measure the low concentrations of such organic materials in drinking water. The carbon technique will yield a measurement and it is possible to compare one water with another. Ettinger has proposed that a 200 ppb concentration of carbon filter chloroform extractables in drinking water be set as a limit that would serve as a toxicity screen. Waters from clean sources rarely exceed 50 ppb of such materials. Waters that exceed 200 ppb are usually of poor quality from the taste and odor standpoint.

Moving to the next more concentrated organically polluted water -- the surface stream and sometimes the ground water -- what use can be made of the carbon technique in our analytical scheme for determining water quality? As with drinking waters, it yields a tangible, weighable portion of pollution and will show pollution from industrial sources not shown by other techniques. By the use of large-scale apparatus, sufficient quantities of materials can be obtained to permit testing for physiological properties.

While it is true that not all toxicants would be captured or recovered from the filter, a large group of materials are recovered. A partial list of chemical contaminants that have been identified in river waters from chloroform extracts include: DDT., aldrin, orthonotrochlorobenzene, tetralin, naphthalene, chloroethyl ether, acetephenone, diphenyl ether, pyridine, lutidine, phenols, nitriles, kerosene, various substituted benzene compounds, synthetic detergents, aldehydes, ketones and alcohols. Most of the contaminants found in river waters also appear in the drinking water.

The number of materials identified undoubtedly is a small percentage of the materials present. Even if toxicity is not a consideration, most of these chemicals can do damage to water by causing taste and odor, and the other effects already mentioned. Certainly such compounds do not improve the water.

The carbon technique is being used in the National Water Quality Network. Major trends of pollution are revealed by the technique and as routinely used the method reveals the presence of the common chlorinated insecticides, DDT, aldrin, dieldrin, methoxychlor, lindane, endrin, and chlordane. Other aromatic chemicals may be recognized also by use of infrared spectrophotometry. Where industrial pollution is heavy, substantial amount of materials can be recovered and identification of contaminants, while not easy, can often be accomplished. This is useful in establishing sources of pollution, persistence, and establishing the causes of damage such as taste and odor.

Going one step further, does the carbon have use in measuring sewage or industrial effluents directly? The method has been applied but little in testing sewage effluents. The COD components are apparently taken up by the carbon but are not recovered with more than 15 or 20 percent efficiency. Concentrations of such contaminants can be sought in other ways. Most materials causing COD in sewage effluents remain unidentified. In fairly dilute industrial waste streams, the carbon can be used although direct liquid extraction procedures will usually be the methods of choice.

In short, the carbon filter has use where the contaminants are dilute. It serves a compositing mechanism but is not very useful on a day-to-day basis. Results, as with any technique, need to be interpreted in the light of conditions causing the contamination. The approach is not a cure-all but if it is used properly in the right circumstances, information is obtained which cannot be obtained in other ways.

It is clear that none of our procedures measure all of the organic contaminants in water or waste. Nor will a combination of the methods reveal the total amounts of organics or the kinds of materials present. However, much can be learned and the results of analysis can be applied to problem solving with judicious selection of testing methods.

We need further methods to describe the organic contaminants in water and waste, and we need a more concerted attack on the problem of analysis using techniques now available. Progress in these areas can and will be made. Technical specialists need to be attracted to work on these problems. The challenges are as great as those in any field.

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RADIOACTIVITY DATA - ITS SIGNIFICANCE

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The National Water Quality Network was initiated October 1, 1957, to obtain long-term information on changes in surface water quality and to provide useful data on water resources.[1] One of the analyses performed on each of the samples submitted weekly was the determination of radioactivity.

After the one liter samples are received at the laboratory, an aliquot is passed through a membrane filter to separate the suspended and dissolved fractions.[2] Separation of the suspended solids fraction provides information on the degree of removal that may be expected by such water treatment processes as coagulation, sedimentation, and filtration which remove particulate matter. Gross activity levels in surface waters have been reported for the period October 1, 1957-September 30, 1958.[1] More extensive data on the levels of activity in the Missouri-Mississippi River basins covering the first year of study were published in 1959.[3] More recently, data on the strontium-90 levels in surface waters in the U. S. have also been published.[4]

This paper reviews radioactivity measurements in surface water samples and illustrates the kinds of information that may be obtained from such analyses and how such data may be interpreted. By means of selected data presentation, specific parameters relating to activity measurements are indicated and their significance evaluated.

RESULTS

Figure 1 shows log-probability distributions of strontium-90 levels in U. S. surface waters for the period October, 1958 through June, 1960 by quarters. It will be seen that the strontium-90 content increased for the first three quarter periods indicated, that is, from October, 1958 through June, 1959. During the next three quarters, the levels fell and, with the exception of the data for July-September, 1959, are all lower than previous values. A slight rise was again indicated for the period April-June, 1960 where the geometric mean value increased from a previous value of 0.52 to 0.63 $\mu\mu c/l$. The decrease in strontium-90 levels observed is expected, inasmuch as there have been no weapons tests since October, 1958 with the exception of the two French shots in the Sahara Desert during the spring of 1960. The increase observed for the period April-June, 1960 reflects runoff from the snows and rains deposited during the previous quarter when the bulk of the weather normally comes from the North. There is an increase

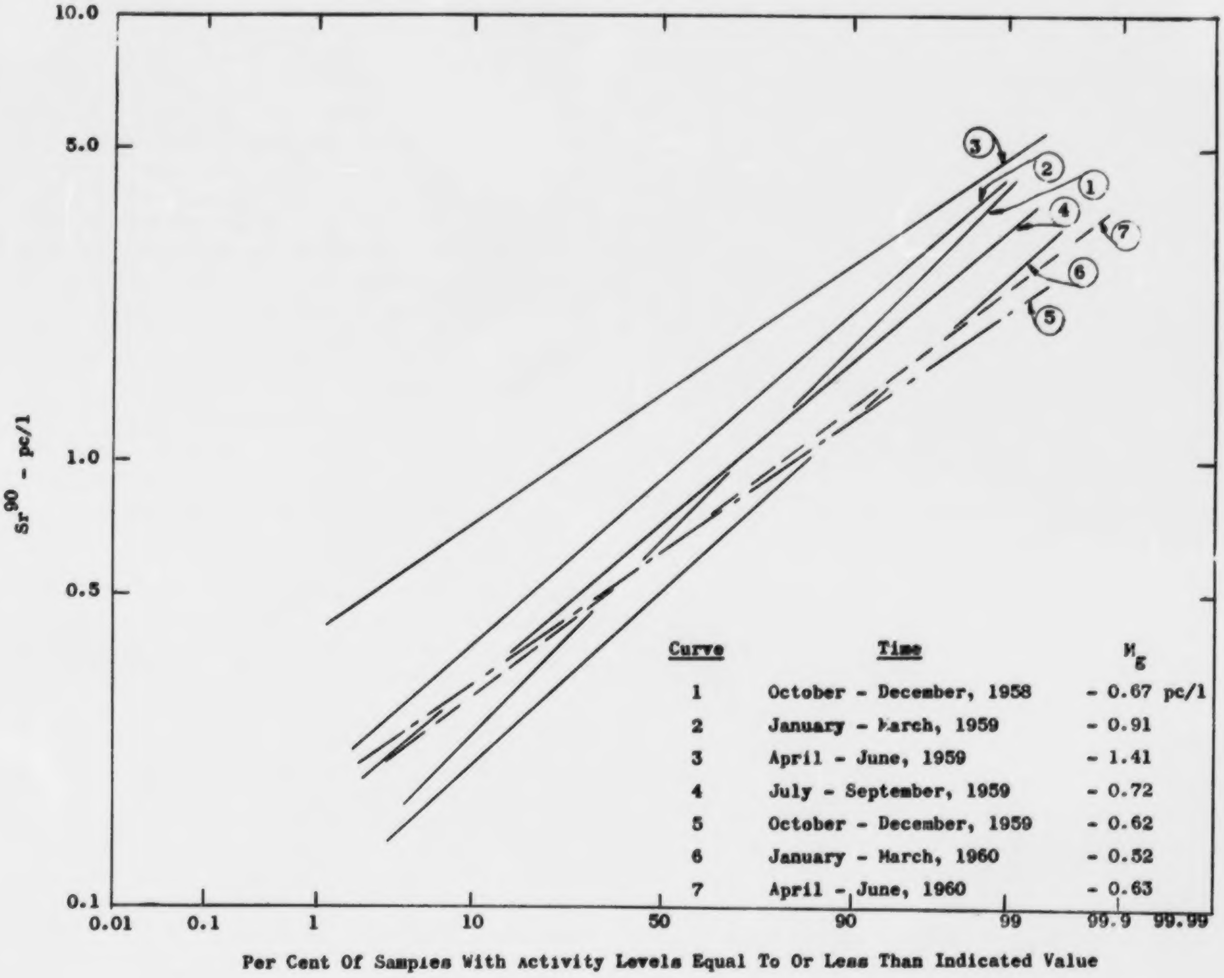

Figure 1. SR^{90} LEVELS IN U. S. SURFACE STREAMS

in radioactivity levels with latitude as one moves northward from the equator. The maximum occurs at 40-60° north latitude.

Figure 2 shows a plot of suspended alpha activity in $\mu\mu c/l$ against suspended solids in mg/l. A rather well defined straight line relation is obtained when these two parameters are plotted on semi-log paper. The data shown represent results of samples taken from the Red River at Alexandria, Louisiana. Where rivers flow through uraniferous soils, the presence of suspended solids containing alpha activity is expected so the relationship shown is not unusual. Attempts to obtain similar relationships with beta activity, as for example at Cincinnati, have shown no relationship between solids content and beta activity of suspended solids even though such a relationship was indicated in data presented by Setter et al.[3] Such a relationship would be expected more reasonably during periods of high radio-

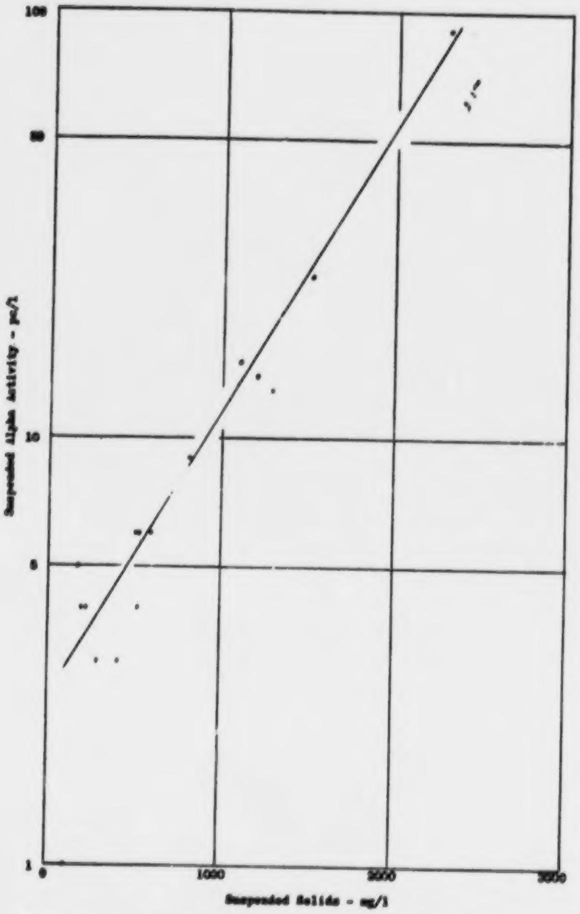

Figure 2. RELATION BETWEEN ALPHA ACTIVITY AND SUSPENDED SOLIDS. Red River, Alexandria, Louisiana.

active fallout rather than currently when radioactivity levels are very low as will be shown subsequently.

Where radioactivity levels are known for rainfall as well as surface waters, the removal taking place by natural agents may be determined as a function of topography, hydrology, geology, and meteorology. Such data have been plotted in Figure 3 where radioactivity in rain is plotted against the decontamination factor, that is, the ratio of radioactivity in rainfall to the radioactivity in surface waters. It will be seen that decontamination factors increase with increased radioactivity in rain. This may be explained by the fact that higher activity levels in rainfall are generally associated with fresh material from weapons tests. The rains contain a high proportion of short-lived radioactive materials that decay rapidly and are readily adsorbed by vegetation or adsorbed and exchanged by soils. Rainfalls that are low in activity generally contain longer-lived materials which are not as readily removed by natural agents, thus accounting for the lower decontamination factors.

Figures 4 and 5 show plots of strontium-90 activity vs. total beta activity and dissolved beta activity in μμc/l in surface waters, respectively. From the scatter diagrams shown, it is obvious that there is no apparent relationship between the parameters concerned. The insert plots in both figures show similar data relating to lake waters with a possible correlation between these parameters.

Table 3 summarizes suspended and dissolved alpha, beta-gamma, and solids levels for 1959 and the first six months of 1960 for sample station locations on the Ohio and Columbia River basins. As can be seen, the alpha activity levels are low. Beta activity levels indicated for 1959 are somewhat higher than those reported for 1960, particularly for the Ohio River basin. This is not true for the lower three stations on the Columbia River basin, namely Pasco, Bonneville, and Beaver Army Terminal, which show approximately similar levels for both periods. Suspended and dissolved solids levels vary somewhat with much more variation shown for the Ohio River basin than for the Columbia River basin as one moves downstream.

Because the data for 1959 given in Table 3 cover such a wide range of activity levels, these data have been re-tabulated in Tables 4, 5, 6, and 7 on the basis of the three half-year periods; January-June, 1959, July-December, 1959, and January-June, 1960. From Table 4, it will be seen that the activity levels associated with the suspended solids above Pasco were low for even the first period when some fallout reached the streams. The levels increased

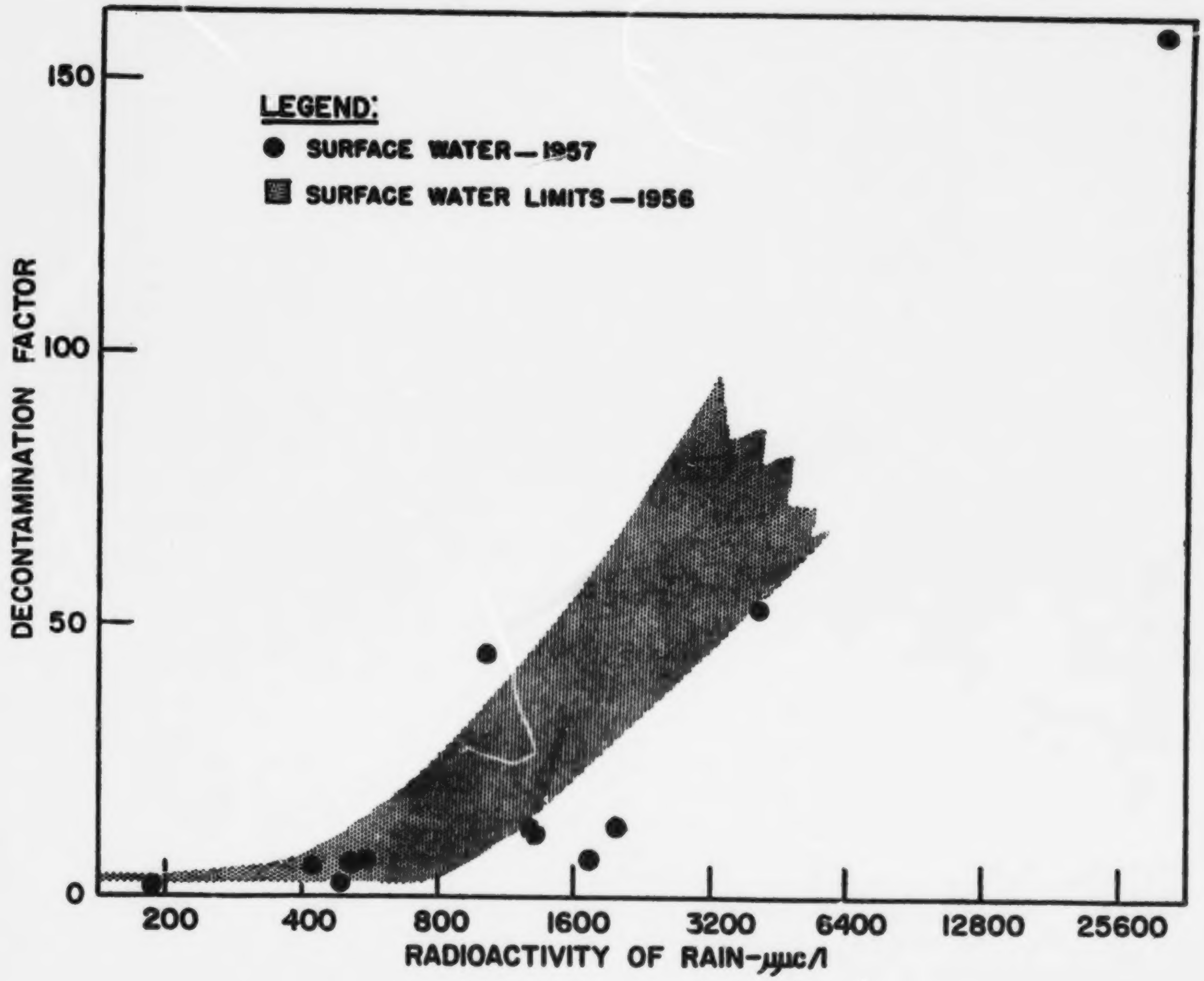

Figure 3. THE DECONTAMINATION OF RAIN BY NATURAL AGENCIES

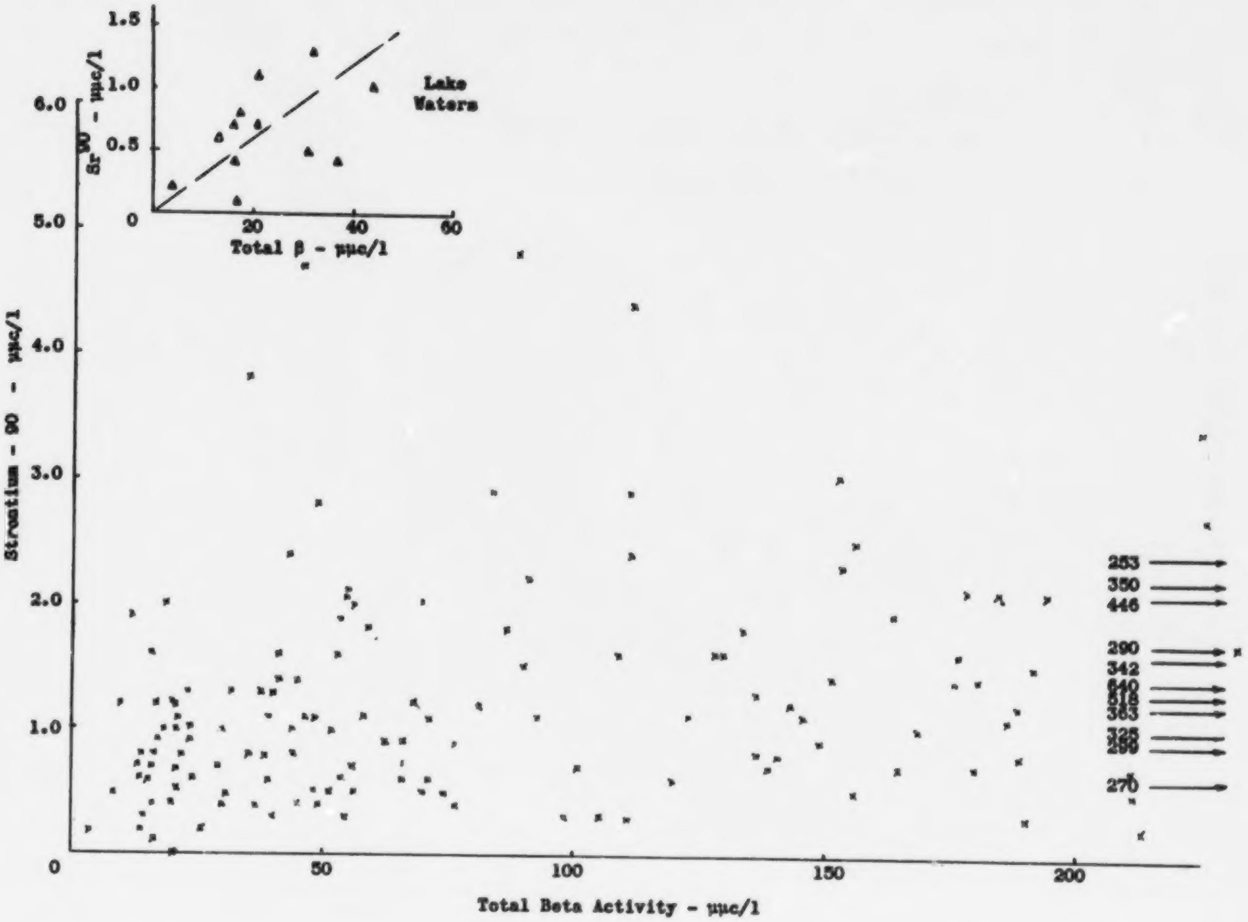

Figure 4. RELATIONSHIP BETWEEN STRONTIUM-90 AND TOTAL BETA ACTIVITY LEVELS.

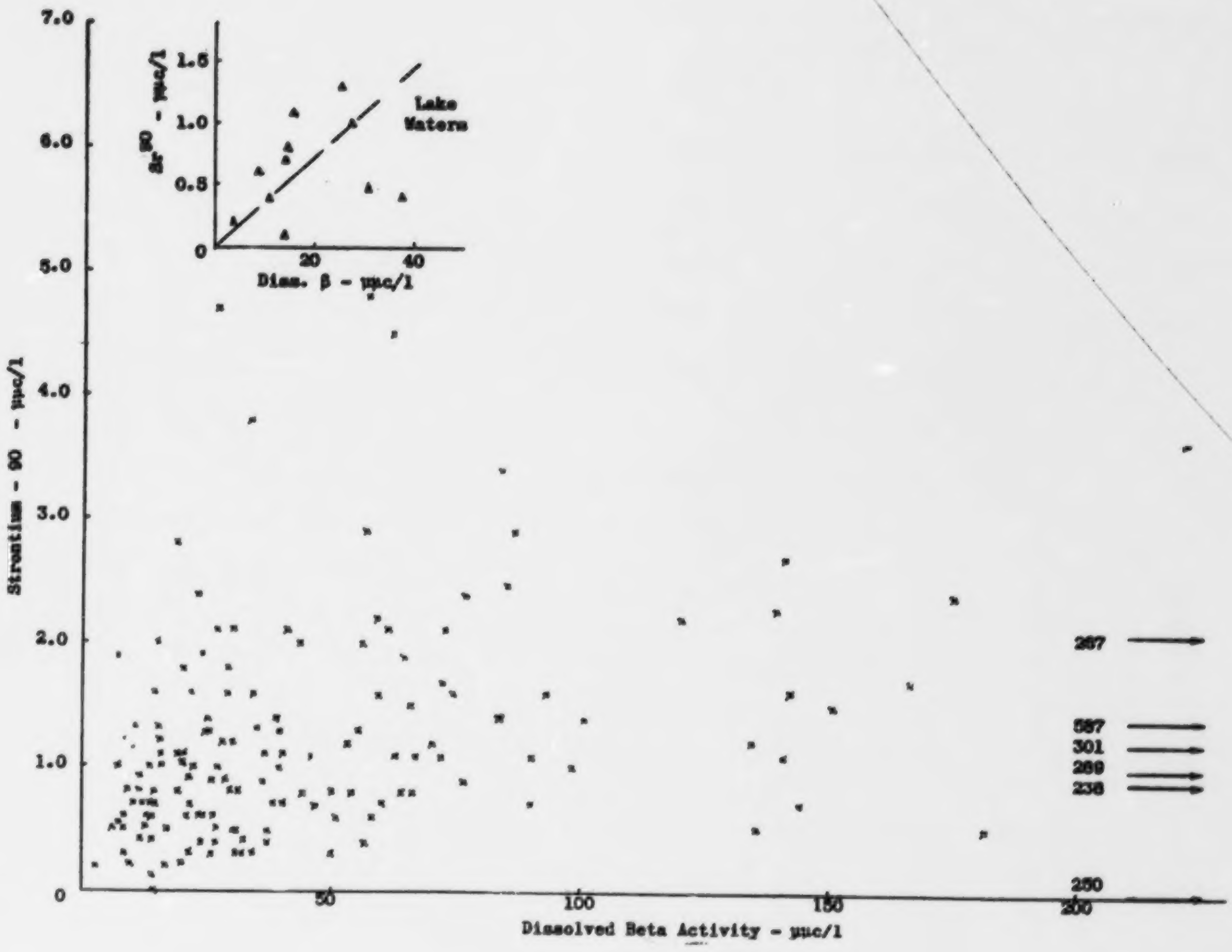

Figure 5. RELATIONSHIP BETWEEN STRONTIUM-90 AND DISSOLVED BETA ACTIVITY.

Table 3. AVERAGE GROSS ALPHA AND BETA ACTIVITY LEVELS AND SUSPENDED AND DISSOLVED SOLIDS CONCENTRATIONS - OHIO AND COLUMBIA RIVER BASINS

	Alpha - μμc/l				Beta - μμc/l				Solids - mg/l			
	Suspended		Dissolved		Suspended		Dissolved		Suspended		Dissolved	
	1959	1960**	1959	1960	1959	1960	1959	1960	1959	1960	1959	1960
East Liverpool	0.8	0.3	0.3	0.1	132*	0	20	1.2	60	12	260	231
Huntington	1.4	2.1	1.0	0.4	32	6.1	31	3.0	86	89	266	218
Cincinnati	3.3	2.6	0.2	0.3	23	5.8	16	7.1	138	125	289	230
Evansville	1.7	2.0	1.7	0.3	38	7.1	25	1.7	114	157	278	226
Cairo	1.1	1.8	0.8	0.9	23	3.5	30	5.7	128	99	272	248
Alsea	0.2	0	1.0	0	4.8	1.2	15	1.6	41	18	112	81
Wenatchee	0.1	0	0.1	0.4	5.9	0.4	23	9.6	49	16	132	139
Pasco	1.4	0	1.2	0.2	61	85	403	428	29	19	137	116
Bonneville	0	0.3	0.2	0.5	43	38	205	191	43	25	165	130
Beaver Army Terminal	0.1	0.1	0.3	0.3	43	26	141	122	47	28	147	115

* A single value of 4492 μμc/l was reported. When this value is omitted from the total, the average value was 17.

** First 6 months of 1960.

from Pasco downstream, and this increase was due, obviously, to operations at Hanford. The activity levels in the suspended solids at Pasco show little difference in values for the three half-year periods. The second and third period values at Bonneville and Beaver Army Terminal were somewhat lower than the first period values. Low levels of radioactivity are observed in the dissolved fraction in the samples collected above Hanford, but a very great increase is indicated for Pasco. These levels drop as one moves downstream. This drop is due to the decay of some of the short-lived radionuclides present and to the removal of these and other radionuclides by natural agents associated with the stream environment. Table 5, which gives a similar breakdown of suspended and dissolved solids data, shows that the operations at Hanford have little effect upon suspended solids concentrations observed.

By way of comparison, similar data have been summarized for the five stations located in the Ohio River basin. As shown in Table 6, there is little variation in the radioactivity levels associated with the suspended and dissolved solids fractions at these stations. Even though there are several nuclear energy establishments on this river basin, they do not appear to affect the gross activity concentrations. Although the difference in suspended solids levels is somewhat variable, as shown

Table 4. MEDIAN VALUES OF BETA ACTIVITY ASSOCIATED WITH SUSPENDED AND DISSOLVED SOLIDS - COLUMBIA RIVER BASIN SAMPLES

Station	Beta Activity - μμc/l					
	Suspended Solids			Dissolved Solids		
	1st*	2nd	3rd	1st	2nd	3rd
Alsea	3(18) (0-52)**	0(23) (0-11)	0(10) (0-12)	10(18) (0-190)	0(24) (0-128)	0(10) (0-16)
Wenatchee	6(24) (0-80)	0(24) (0-10)	0(13) (0-2)	19(24) (0-286)	3(24) (0-15)	0(13) (0-8)
Pasco	68(26) (4-207)	47(26) (2-140)	62(25) (8-560)	428(25) (80-1060)	382(26) (82-817)	395(25) (133-1064)
Bonneville	50(26) (0-141)	19(18) (6-86)	36(12) (8-76)	190(26) (21-486)	228(18) (73-391)	168(12) (69-408)
Beaver Army Terminal	57(25) (3-167)	19(22) (5-71)	21(26) (8-148)	115(24) (61-347)	149(22) (51-218)	75(25) (38-799)

* 1st - January-June, 1959; 2nd - July-December, 1959; 3rd - January-June, 1960.

** First number represents the median value; the next single number in parentheses, the number of samples from which the median value was determined; the next numbers in parentheses, the range of values encountered during the period.

Table 5. MEDIAN VALUES OF SUSPENDED AND DISSOLVED SOLIDS - COLUMBIA RIVER BASIN SAMPLES

Station	Suspended Solids - mg/1			Dissolved Solids - mg/1		
	1st*	2nd	3rd	1st	2nd	3rd
Alsea	20 (18) (3-120)**	30 (23) (3-230)	16 (10) (8-34)	88 (18) (60-524)	92 (23) (40-275)	77 (10) (47-113)
Wenatchee	26 (24) (9-227)	22 (24) (1-61)	16 (13) (7-28)	138 (24) (92-200)	119 (24) (87-276)	125 (13) (95-238)
Pasco	26 (25) (6-107)	28 (26) (3-59)	18 (25) (6-51)	144 (25) (91-328)	118 (26) (20-245)	112 (25) (57-157)
Bonneville	32 (26) (7-174)	26 (18) (17-57)	24 (12) (6-51)	152 (26) (26-304)	138 (13) (106-379)	133 (12) (120-144)
Beaver Army Terminal	32 (24) (14-115)	33 (22) (12-60)	25 (25) (8-49)	(133) 24 (81-399)	114 (22) (43-332)	117 (25) (64-158)

* 1st - January-June, 1959; 2nd - July-December, 1959; 3rd - January-June, 1960.

** First number represents the median value; the next single number in parentheses, the number of samples from which the median value was determined; the next numbers in parentheses, the range of values encountered during the period.

Table 6. MEDIAN VALUES OF BETA ACTIVITY ASSOCIATED WITH SUSPENDED AND DISSOLVED SOLIDS - OHIO RIVER BASIN SAMPLES

Station	Beta Activity - μμc/l					
	Suspended Solids			Dissolved Solids		
	1st*	2nd	3rd	1st	2nd	3rd
East Liverpool	29(23) (0-4492)**	0(16) (0-20)	0(12) (0)	22(24) (0-92)	1(15) (0-30)	0(12) (0-7)
Huntington	35(26) (0-265)	0(25) (0-40)	0(14) (0-32)	26(26) (0-328)	6(24) (0-84)	0(14) (0-20)
Cincinnati	46(24) (0-250)	1(27) (0-30)	2(14) (0-39)	22(24) (0-63)	14(27) (0-62)	0(13) (0-22)
Evansville	28(12) (0-142)	2(2) (0-5)	2(13) (0-27)	16(12) (7-80)	16(2) (13-19)	2(12) (0-7)
Cairo	34(26) (2-139)	1(25) (0-32)	1(14) (0-12)	36(26) (0-242)	3(25) (0-38)	0(13) (0-33)

* 1st - January-June, 1959; 2nd - July-December, 1959; 3rd - January-June, 1960.

** First number represents the median value; the next single number in parentheses, number of samples from which the median value was determined; the next numbers in parentheses, the range of values encountered during the period.

Table 7. MEDIAN VALUES OF SUSPENDED AND DISSOLVED SOLIDS
OHIO RIVER BASIN SAMPLES

Station	Suspended Solids-mg/l			Dissolved Solids-mg/l		
	1st*	2nd	3rd	1st	2nd	3rd
East Liverpool	56(24) (5-181)**	38(15) (18-155)	32(11) (13-80)	164(24) (83-508)	332(15) (61-610)	233(11) (119-306)
Huntington	82(26) (17-594)	48(25) (18-232)	71(13) (17-340)	202(26) (87-380)	341(24) (78-632)	207(13) (128-410)
Cincinnati	143(24) (32-608)	68(27) (22-411)	118(13) (55-187)	204(24) (124-447)	372(27) (94-975)	233(13) (175-317)
Evansville	90(12) (34-443)	46(2) (42-49)	66(12) (26-490)	233(12) (162-423)	375(2) (366-384)	224(12) (120-289)
Cairo	120(26) (20-1134)	57(25) (20-366)	88(13) (10-290)	282(26) (167-623)	217(25) (97-492)	230(13) (220-324)

* 1st - January-June, 1959; 2nd - July-December, 1959; 3rd - January-June, 1960.

** First number represents the median value; the next single number in parentheses, the number of samples from which the median value was determined; the next numbers in parentheses, the range of values encountered during the period.

in Table 7, an increase in dissolved solids is observed, particularly for the period January-June, 1959. With the exception of the July-December, 1959 data for Cairo which is low in dissolved solids, all other stations show approximately the same level ranging from 332 to 375 mg/l. The data for the third half-year period are even more uniform in that the range of dissolved solids concentration is from 207 to 233 mg/l.

Table 8 shows approximate half-lives of radioactive material found in the Columbia River at Pasco, Bonneville, and Beaver Army Terminal. It will be seen that the values range anywhere from 10-45 days. This would represent a mixture of phosphorus-32, chromium-51, and zinc-65, as well as other short-lived radionuclides. Gamma scans of two samples are shown in Figures 6 and 7. Figure 6 shows the evidence of a prominent zinc-65 peak and some evidence of Ru^{106}-Rh^{106}. This was a sample of Bonneville and Pasco waters. The fact that only zinc-65 and ruthenium-106 were prominent indicates that the age of this material was something in the order of one year. Figure 7 shows a gamma scan of a sample collected March 21, 1960 at Pasco. This sample contained 949 μμc/l of beta activity. Peaks of cerium-141,144, chromium-51, and zinc-65 are rather prominent.

The activity levels found in the suspended and dissolved solids fractions of samples from the five stations on the Ohio River for the period January-June, 1959 are listed in Table

Table 8. APPROXIMATE HALF-LIVES IN DAYS OF RADIOACTIVITY ASSOCIATED WITH SUSPENDED AND DISSOLVED SOLIDS FRACTIONS. SAMPLES TAKEN AT PASCO, BONNEVILLE, AND BEAVER ARMY TERMINAL, COLUMBIA RIVER

Date	Half Life in Days					
	Suspended Solids Fraction			Dissolved Solids Fraction		
	Pasco	Bonneville	Beaver A. T.	Pasco	Bonneville	Beaver A. T.
1/12/59	23	33	13	14	30	27.5
1/19				23.1		
1/26	31			24.2	24	
3/2	31			18.5		
3/16		33				
3/23	14.7			20	28	
4/27	10			21	36	
5/4	11.6		12	15		
5/11			9.5			10.5
8/10	19			26		
9/8	13					
10/5						33
10/26						28
11/2						27
11/9	26			19	34.5	
11/16						33
11/23	20			25	37.5	
1/4/60	24			28.5	32	31
2/23	29		23.3	29	31.5	45.5
3/7			47			
3/14	39.5			26.5		
3/21	19			25.5	24	41.5
3/28	33.5			28		
4/4	16.8			24	33	34

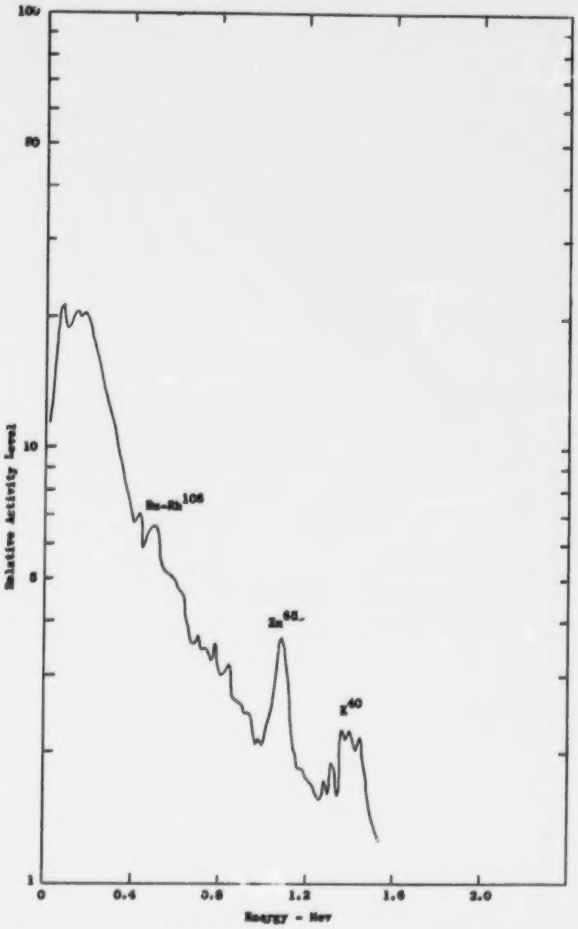

Figure 6. GAMMA SCAN - Bonneville and Pasco.

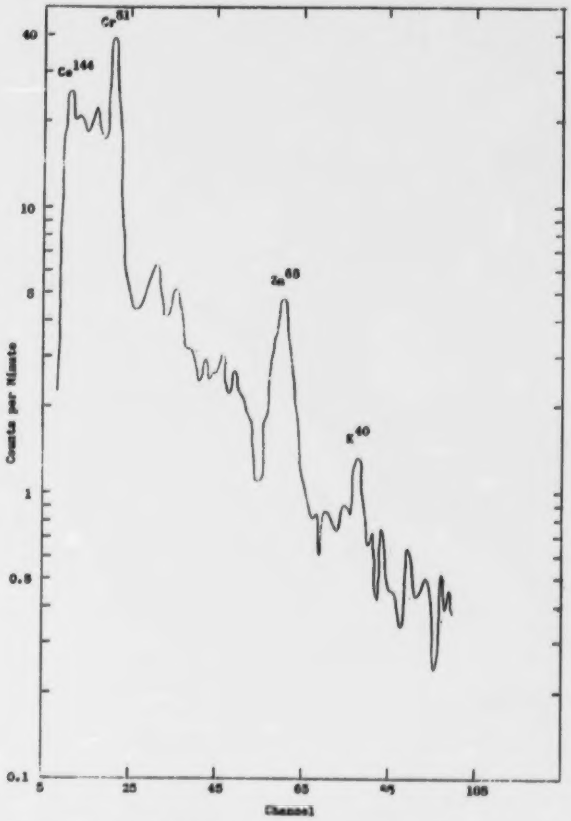

Figure 7. GAMMA SCAN - Pasco sample collected 3/21/60.

9 along with average flow values. From these data can be calculated the number of curies of total activity in water passing each station. These values are included in the last two columns of Table 9 and show that there has been a marked variation in the activity levels associated with the suspended solids fraction in curies/day with a general increase from approximately 4 to 27.2 curies/day. The activity associated with the dissolved fraction in curies/day ranged from 3.0 at East Liverpool to 28.8 at Cairo with substantially constant values in the order of 7 curies/day for the three intermediate stations. Activity levels increased markedly in both the suspended and dissolved solids fractions in the stretch of river between Evansville, Indiana and Cairo, Illinois. This increase could have been due to the radioactivity contributed by the Tennessee River system which discharges into the Ohio east of Cairo. The Tennessee River receives wastes from the Oak Ridge National Laboratory which could account for some of this increased radioactivity. Activity levels in wastes released by Oak Ridge National Laboratory have been published by Morgan[5].

With activation of the Interstate Quarantine Network which will also include the measurement of radioactivity, it will be possible to compare activity levels in raw and finished waters and to determine the efficiency of municipal water treatment processes for the removal of gross activity. To provide data on this particular subject, some material from reports of the South District Filtration Plant, Chicago, Illinois, have been extracted to show the efficiency of the treatment processes used

Table 9. RADIOACTIVITY LOAD AT VARIOUS STATIONS - OHIO RIVER
January - June, 1959

Station	Activity, $\mu\mu c/l$ Suspended fraction	Activity, $\mu\mu c/l$ Dissolved fraction	Flow cfs	Curies per day Suspended fraction	Curies per day Dissolved fraction
E. Liverpool	29	22	56,100	4.0	3.0
Huntington	35	26	111,150	9.5	7.0
Cincinnati	46	22	137,400	15.4	7.4
Evansville	28	16	179,500	12.3	7.0
Cairo	34	36	328,000	27.2	28.8

for the removal of gross activity. Removal efficiencies ranging from 13-64 per cent for the period January, 1958 through January, 1960 are shown. The average removal value reported was 38 per cent. This demonstrates the ineffectiveness of water treatment processes, even with the extensive treatment provided at Chicago for removal of gross radioactivity.

DISCUSSION

Plots similar to Figure 1 are useful in predicting probable activity levels. Thus, it is seen that the peak value of 5 $\mu\mu c/l$ would be expected to occur approximately one per cent of the time, based on the activity levels occurring in the series April through June, 1959. With the drop in general levels that has taken place since then, a value of this magnitude would occur approximately once in 5,000 samples.

With the exception of the values indicated for the Columbia River below Pasco, the highest gross activity level in the suspended solids fraction since July, 1959 amounted to 40 $\mu\mu c/l$. The highest dissolved solids activity level during this same period was 128 $\mu\mu c/l$. Since water treatment processes will remove essentially all of the suspended solids and a portion of the dissolved solids, these levels are not very high. Of more significance than the gross activity levels are nuclide concentrations inasmuch as these must be known if potential hazard from ingestion is to be evaluated.

In the past, many individuals were enamored with the use of a gross activity value of 100 $\mu\mu c/l$ which was given in National Bureau of Standards Handbook 52[6], as a control level. However, these same individuals did not recognize the limitation placed upon this value, namely, that it be applied for short periods pending identification of the specific radionuclides constituting the gross activity level and that, following such identification, the individual MPC values be applied for the given nuclides. In the more recent releases of the National Committee on Radiation Protection (NCRP)[7] and International Commission on Radiological Protection (ICRP)[8], specific permissible levels of gross radioactivity are suggested in the absence of the more critical alpha and beta emitters.

Since the alpha activity, the strontium-90, and the gross activity values reported are low, the activity levels encountered, even in the case of the three lower stations on the Columbia River, pose no particular problem insofar as water is concerned. Currently, radioactivity concentration guides are under development by the Federal Radiation Council. No specific numerical recommendations for Radioactivity Concentration Guides are provided at this time. However, concentration guides now used by the agencies appear appropriate on an interim basis. Accordingly, comparisons will have to be made of current environmental levels with values recommended by the NCRP[7] and ICRP[8]. The peak value of five $\mu\mu c/l$ of strontium-90 may be compared to an average population MPC value of 33 $\mu\mu c/l$[8] or a maximum level for individuals in special group B.c. of about 100 $\mu\mu c/l$[8]. Thus, current average levels ($M_g = 0.63\ \mu\mu c\ Sr^{90}/l$) represent less than two per cent of the average permissible population level. It must also be remembered that the permissable levels indicated were arrived at for continuous exposure over a period of 50 years.

Water treatment plants providing coagulation and filtration would remove essentially all of the radioactivity associated with the suspended solids and only a portion of that associated with the dissolved solids. Thus, with reference to the data in Table 9, at least 57 per cent of the activity could be removed at East Liverpool, 57 per cent at Huntington, 67 per cent at Cincinnati, 64 per cent at Evansville, and only 48 per cent at Cairo.

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WATER QUALITY PARAMETERS

DISCUSSION

MR. HAROLD ROMER (Bureau of Sanitary Engineering, New York City Health Department): Dr. Kabler, I would like to inquire of your experience with the growth of coliform organisms in distribution systems. First, where there is a good kill by virtue of chlorination (with some residual coliforms that are bound to get by); and second, where there is good quality surface water without chlorination. What growth, if any, can be anticipated in the menstruum?

DR. PAUL W. KABLER (Chief, Microbiology Section, Research Branch, Division of Water Supply & Pollution Control, Public Health Service, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio): I can't answer that question for you actually on data from distribution systems. From laboratory data we have found that the coliforms will grow in a menstruum that contains less than 50 parts per million organic material, and sometimes much below that. So where you have an old system or have any system with sediment present that does, or is likely to, contain organic material and the sediment is seeded with coliform organisms, I believe you can expect to have the coliform organisms persist for a considerable period of time.

MR. ROMER: Would you expect growth?

DR. KABLER: I think you would have to call it that. The cell, the same cell as such, probably doesn't persist for months or years at a time, and even though the numbers actually attained may not be large, there must be some division of organisms present. I believe this would be considered growth.

MR. ERWIN COHEN (Research Chemist, American Machine and Foundry, Springdale, Conn.): Dr. Kabler, we have been setting up some taste panels for water, and we routinely send the water out for a coliform test before we taste it. However, we have found in some cases that where there are a lot of bacteria present other than coliform, some of our panel members have been complaining about ill effects. How reliable is our coliform test in this respect?

DR. KABLER: The coliform test is not a test for all possible deleterious effects. It would require much more information on these ill effects that you mention to make an evaluation. It might be that you should add a psychiatrist to your panel.

MR. DAVID E. SIMON II (Engineer, Cyrus W. Rice & Co., Pittsburgh, Pa.): Mr. Middleton, have you determined in any way how much of the material which is absorbed on the carbon is extractable by means of chloroform and alcohol? For instance have you put extracted material back onto carbon and then attempted to recover it again?

MR. FRANCIS M. MIDDLETON (Chemistry & Physics Section, Research Branch, Div. of Water Supply & Pollution Control, Public Health Service, Robt. A. Taft Sanitary Engineering Center, Cincinnati, Ohio): Working with certain known materials we ordinarily can get back 50 or 75 per cent of such material as phenol. We haven't done any work on taking the materials that have come off of carbon readsorbing them and then trying to recover them again. A group at Washington University has tried this and they find that once the materials have been on the carbon they come off again a second time rather easily.

Some materials, such as chlorinated insecticides, can be recovered with 90 per cent efficiency. In the case of alkyl benzene sulfonate you cannot remove it from carbon with chloroform, but with a mixture of benzene, methanol and ammonia, you will get all of it back. Chloroform extraction takes off many organics but it does not take off everything.

MR. IRVING LEVY (Graduate School of Public Health, University of Pittsburgh): Mr. Middleton, what progress has been made in determining the exotic organics in the streams by spectrographic methods?

MR. MIDDLETON: Using spectrographic methods, mostly infrared, we have managed to identify a fairly large number of materials. We have found and identified insecticides in water, DDT and Aldrin, specifically. I have already mentioned ortho-nitrochlorobenzene, acetonitrile, a large number of substituted benzenes, alcohols, ketones, and so on. Collection is by carbon filter, followed by column or gas chromotography and then infrared. These procedures work well on the more volatile portions of the samples.

BASIC CONSIDERATIONS IN SAMPLING OF TIDAL WATERS

THOMAS R. GLENN, JR., Director & Chief Engineer
Interstate Sanitation Commission, New York, N.Y.

The Interstate Sanitation Commission was created by the States of New York, New Jersey and Connecticut for the abatement of existing and the control of future pollution in the waters of the New York-Metropolitan Area.

The Compact recognizes that because of the varied uses of these waters - for bathing, navigation, shellfish culture, fishing and the disposal of wastes, no single standard of water quality is economically practical. After public hearings, the waters of the District were classified according to their best usage and corresponding effluent standards were established.

Water area evaluation surveys are required to determine the effectiveness of the pollution abatement program in different parts of our District. They furnish the information on minimum treatment required to maintain conditions for best usage of the water. It should be pointed out that waters under our jurisdiction are all tidal and pose a variety of problems not encountered in non-tidal pollution abatement work.

The subject of our panel discussion is "Water Quality Data Use," but some discussion is necessary on what data must be obtained before determining what use may be made of it. There has been a great amount of sampling in different areas of tidal waters over a period of many years. However, the manner in which the data was taken prevented it from being used except in a very general way.

There are certain basic considerations in the sampling of tidal waters that should be followed or it may be found that the data, though quite voluminous, may be of little practical value. In trying to analyze data collected over a long period of time, with existing methods of analysis, wide variations as to the water quality were obtained. In some cases, no improvement could be demonstrated after a new sewage treatment plant was placed into operation. It was obvious that it was not because of the lack of improvement but due to a non-sensitive method of obtaining and analyzing data.

Investigation of previous surveys indicated that due to a desire to obtain complete information, numerous tests were made including: dissolved oxygen, B.O.D., coliform, iron, salinity, alkalinity, acidity, and often other tests. The very number of tests limited the number of samples that could be reasonably processed by a laboratory in one day.

In 1957, the Commission planned to run a survey of the Arthur Kill, which is a waterway separating New Jersey from Staten Island and is approximately thirteen miles in length. It was decided to concentrate on running as many dissolved oxygen samples as possible and limit additional tests to salinity and temperatures so that the percent saturation of dissolved oxygen could be calculated. We used percent saturation instead of parts per million of dissolved oxygen for two reasons. One, the standards of the Commission require that certain minimum percent saturation of dissolved oxygen levels be maintained in its various waters. Two, it eliminates the variables of temperature and salinity, and therefor reduces the variation in data.

Eighteen sampling stations were selected and each was sampled three times a day, four days a week, for five weeks. In plotting up the data for individual stations, we found that the dissolved oxygen from many of the stations followed the sinusoidal variation of the tidal current cycle. In a program of random sampling, samples are taken over a period of days and from many tidal current cycles of different lengths. This type of sampling is considered advantageous in that there is no attempt to sample one specific part of the current cycle. By sampling a given station at approximately the same hours each day, all phases of a current cycle are gradually sampled as the time of maximum ebb current changes continually. Thus, the percent saturation existing for all stages of the cycle will be observed in time.

To reduce the observations from various tidal cycles to one common theoretical cycle. which has the distribution of a sine curve, it is necessary to refer all observations to the same current condition. The mean percent saturation of dissolved oxygen, under these conditions, occurs at the time of maximum ebb and flood currents. Here the maximum ebb current is used as the reference time. Thus, to reduce the observations in the various tidal cycles to one common theoretical cycle, which has the distribution of the sine curve, the lapse of time is determined between the time of observation and the time of the last maximum ebb current. This time is referred to as "t". The length of the particular current cycle is obtained from "The Current Tables of the Atlantic Coast of North America" and is referred to as "p". To place a particular observation on the sine curve, we use the expression $\emptyset$, in degrees, equal to $\frac{t}{p} \times 360°$.

In a similar manner, the foregoing procedure is used to obtain a distribution curve which expresses all observations for each station on a common and comparable basis with each other. The graph of the observed data should be plotted with the percent saturation of dissolved oxygen on the vertical scale versus degrees on the horizontal scale. The variation of the observed percent saturation is shown by such a graph for a particular station and, as considered thus far, is most accurately described by a sinusoidal curve of best fit. However, certain geographical conditions, tidal actions and concentration of pollution may cause the distribution of observed data for a few stations to be best described by a straight line, parabola, or various combinations of curves. These curves or lines are determined by the method of least squares, and regression analyses are made to determine the significance of these lines of best fit. Thus, in processing the Arthur Kill survey data, a new method for analyzing observed data in tidal waters was developed by the Commission staff.[1]

An application of this new method of analysis for tidal waters may be shown by the results obtained from the Arthur Kill Survey.[2] On Figure 8, the Arthur Kill Survey Sampling Stations are located. Due to tidal influence, the percent saturation values were found to vary depending on the sampling station and the particular stage of the ebbing or flooding current which happened to be sampled. When the Raritan Bay is flooding, its waters flow northerly into the Arthur Kill. These waters were higher in dissolved oxygen than those in the middle portion of the Kill. When the Raritan Bay is ebbing, the waters in the Arthur Kill flow southerly into the Raritan Bay. With the flow going in this direction, some of the better waters from Newark Bay were drawn into the Arthur Kill.

Figure 12 shows the weighted mean percent saturation of dissolved oxygen for a period of five weeks. At each of the stations, averages were found by the method referred to previously.

Figure 13 shows observed hourly variations of percent saturation of dissolved oxygen during the ebb current phase. The curves of best fit were used to obtain percent saturation of dissolved oxygen values occurring simultaneously at other stations in the Kill. At the start of the ebb current, it maybe seen that the dissolved oxygen is low between Stations No. 1 and No. 7, but as the ebb current proceeds through the fifth hour, the lower section has moved between Station No. 7 and No. 13. Figure 14 is for the flood cycle and the badly polluted water may be observed moving northerly to its initial position.

By studying Figures 13 and 14, it is apparent that a "slug" of polluted waters is oscillating back and forth in the Kill. The southernmost point to which this slug of pollution extended was Station No. 14. At the northerly end, an investigation of the tidal currents showed that the flood current carries Kill waters into Newark Bay for approximately six hours during the flood stage. During the last hour of this flood current at Station No. 1 in the Arthur Kill, the waters were also being pushed across the lower end of Newark Bay into the Kill Van Kull. The waters in the lower end of Newark Bay were also at this time ebbing out through the Kill Van Kull and into the Upper Bay. This slug of pollution in the Arthur Kill is restricted or controlled by this continuous "sloughing off" of its northern end to the Kill Van Kull to balance the pollution which is continually discharged into the Arthur Kill. The The hourly variation of percent saturation occurring throughout the Arthur Kill at specific times during the tidal cycle presents a clear picture of actual conditions. Graphs of minimums and maximums are artificial and would not have revealed the movement of the slug.

Figure 9 shows the sampling stations used in the 1958 Upper New York Harbor Survey which was similar to the survey made in the Arthur Kill. Using the previous methods of analysis, no slug was found in this area. Each curve on Figure 15 shows the variation of the weighted mean percent saturation of dissolved oxygen values through the Main Channel of the Upper New York Harbor for three different B.O.D. loadings. Note the smoothness of these average value curves and that they resemble the shape of the oxygen sag curve.

Set 1 curve is for the first five weeks of the survey. Due to construction work at one of the large treatment plants, untreated sewage was discharged to the Upper Harbor for two weeks. The curve for Set 2 shows the resulting conditions produced by the additional pollution.

Set 3 curve represents the partial recovery in the waterway following resumption of operation of the plant. Set 3 did not recover to the Set 1 conditions for two reasons. One, not enough time was given for a complete recovery before sampling was begun and two, more treated effluent was put out in the Upper Harbor during Set 3, where in Set 1 a greater portion was being bypassed into another water area. This particular survey made it possible to predict future conditions with accuracy and gave a positive measurement of the effect of a definite amount of B.O.D. being added to the water area, with the resulting change in dissolved oxygen content.

A regression curve was developed for the weighted mean values found in the Upper Harbor. In the future, it may be used with limited sampling to determine the conditions throughout the harbor.[3]

Figures 10 and 11 show the location of the sampling stations used for the East River Survey in 1959. Figures 16 and 17 show the movement of a slug that was observed in the East River. Figure 18 is the weighted mean of the percent saturation of dissolved oxygen values. We wish to point out the oxygen sag form of this latter curve. The preliminary report of the East River Survey has just been completed.[4]

These illustrations have employed dissolved oxygen as the parameter for measuring pollution. Data obtained on B.O.D. and salinity may be analyzed by the same method. Many stations exhibiting sinusoidal variations for dissolved oxygen, B.O.D. and salinity fail to follow any pattern when using coliform data.

We are conducting surveys which we hope will produce a method whereby the assimilative capacities of tidal water areas may be more accurately determined. This would allow us to observe data and calculate directly the effect of the removal of a certain amount of B.O.D. from a particular water area. Thus, a yardstick would be provided for determining the effectiveness of the pollution abatement program and aid in estimating any control required in an area.

We believe the next step in obtaining sampling data should be to pick locations for installation of continuous sampling equipment. We do not believe that in tidal waters proper locations for continuous sampling equipment can be made without the prior extensive surveys to obtain the overall characteristics of the water area. Limited sampling may permit erroneous conclusions: (a) by assuming sinusoidal variation for analyzing data when this type of variation does not exist, and (b) some stations will vary by as much as 50 percent saturation of dissolved oxygen during one tidal cycle. After the extensive survey, a limited number of continuous sampling devices will allow the control agency to calculate conditions in all portions of waters under its jurisdiction.

How then would an interstate agency such as ours make use of information obtained by continuous sampling? Our Commission is quite different from many interstate types of commissions. The majority of interstate agencies do not have standards or enforcement powers and their duties are limited to act as a coordinating agency and making recommendations to participating states. Our standards are of the

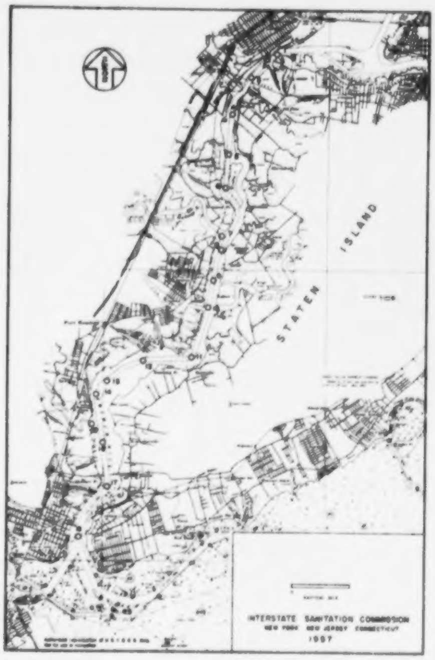
STATEN ISLAND
NAUTICAL MILE
INTERSTATE SANITATION COMMISSION
NEW YORK NEW JERSEY CONNECTICUT
1957

Figure 8. ARTHUR KILL SURVEY SAMPLING STATIONS.

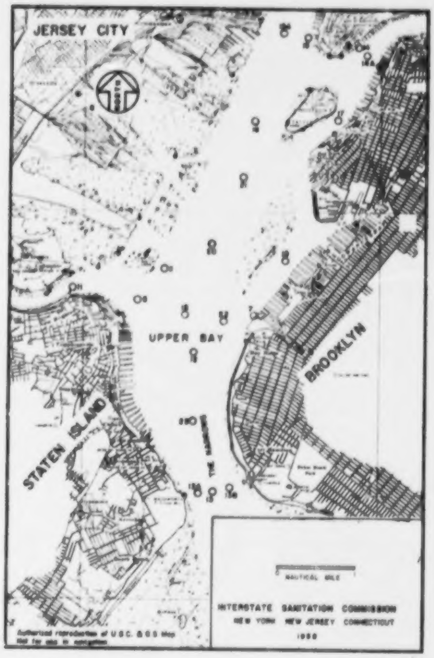
JERSEY CITY
UPPER BAY
BROOKLYN
STATEN ISLAND
NAUTICAL MILE
INTERSTATE SANITATION COMMISSION
NEW YORK NEW JERSEY CONNECTICUT
1958
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Figure 9. UPPER NEW YORK HARBOR SURVEY SAMPLING STATIONS.

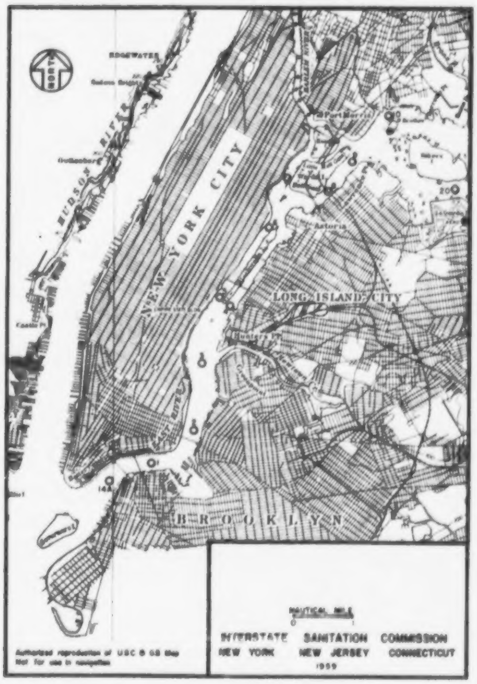
EDGEWATER
HUDSON RIVER
NEW YORK CITY
LONG ISLAND CITY
Astoria
Port Morris
BROOKLYN
NAUTICAL MILE
INTERSTATE SANITATION COMMISSION
NEW YORK NEW JERSEY CONNECTICUT
1959
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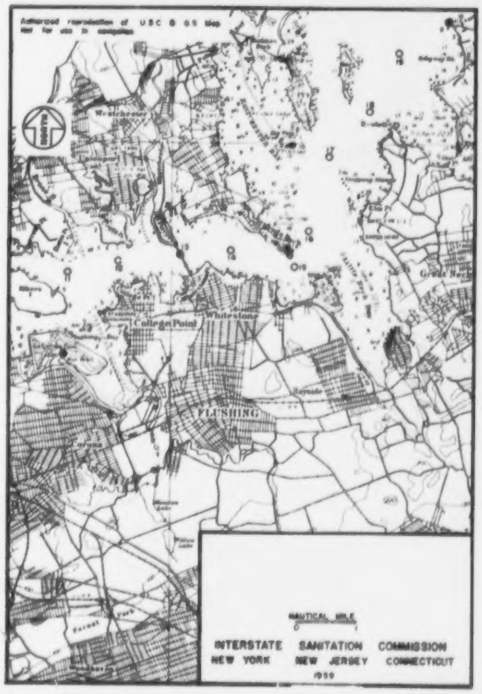
Figure 10. EAST RIVER SURVEY SAMPLING STATIONS, THE BATTERY TO RIKERS ISLAND.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Westchester
College Point
Whitestone
FLUSHING
NAUTICAL MILE
INTERSTATE SANITATION COMMISSION
NEW YORK NEW JERSEY CONNECTICUT
1959

Figure 11. EAST RIVER SURVEY SAMPLING STATIONS, RIKERS ISLAND TO GANGWAY ROCK.

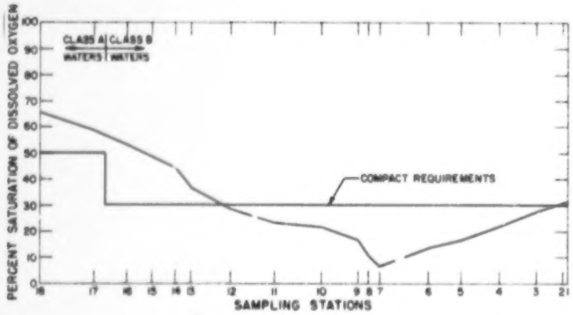

Figure 12. WEIGHTED MEAN PERCENT SATURATION OF DISSOLVED OXYGEN, 1957 ARTHUR KILL SURVEY.

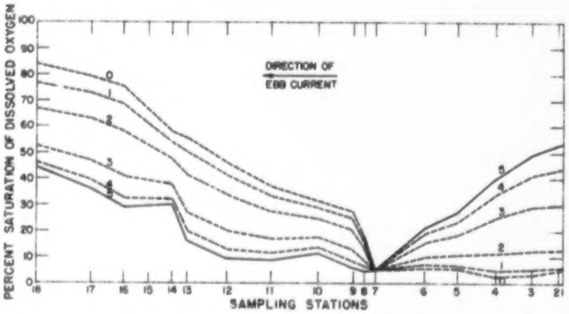

Figure 13. OBSERVED HOURLY VARIATION OF PERCENT SATURATION OF DISSOLVED OXYGEN, EBB CURRENT PHASE, 1957 ARTHUR KILL SURVEY.

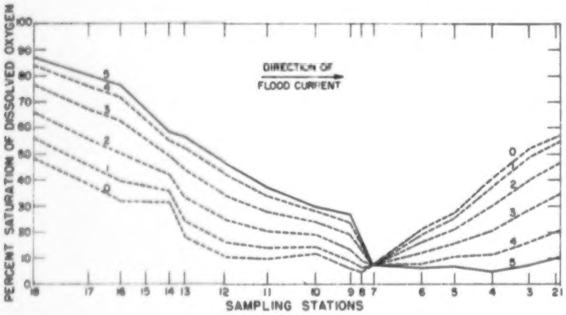

Figure 14. OBSERVED HOURLY VARIATION OF PERCENT SATURATION OF DISSOLVED OXYGEN, FLOOD CURRENT PHASE, 1957 ARTHUR KILL SURVEY.

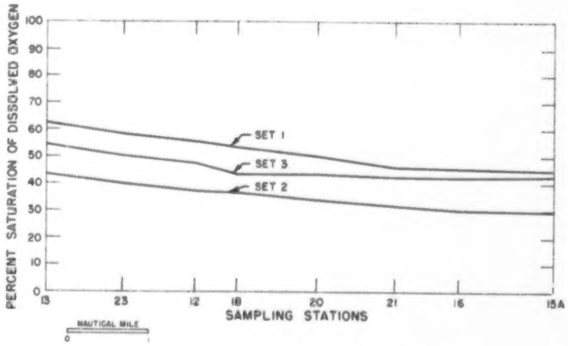

Figure 15. WEIGHTED MEAN PERCENT SATURATION OF DISSOLVED OXYGEN, MAIN CHANNEL, UPPER NEW YORK HARBOR SURVEY 1958.

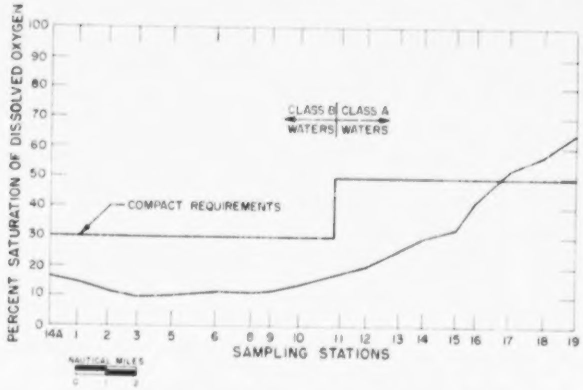

Figure 16. WEIGHTED MEAN PERCENT SATURATION OF DISSOLVED OXYGEN, 1959 EAST RIVER SURVEY.

effluent type and for domestic sewage treatment plants the requirements are spelled out in specific detail. The standards for industrial wastes include these specific conditions and are also covered in a broader way in other sections of the Compact.

Since the Commission is obligated to assure each of the participating states that the treatment plants within its District are meeting Compact requirements, the sampling of treatment plants is one of our major activities. The results of these investigations indicate the effectiveness of the treatment plants and make it possible to detect those that have become obsolete or overloaded. Corrective measures may then be taken to insure their continued compliance with our effluent standards.

From its inception, the Commission attempted to obtain its objectives in enforcing these standards by means of persuasion. It made a strenuous effort to avoid the exercise of power and authority granted to it. The Commission has had excellent cooperation from the various state agencies, especially those charged with water pollution control in each of the three member states.

When it appears that it might be necessary to issue an order, the Commission first uses every means at its disposal to convince the municipal governmental authorities of the need for voluntary procedure to abate pollution. When all other means have been exhausted and further progress cannot be made, a hearing is held for the purpose of affording the municipality the opportunity of showing cause why an order should not be issued. Prior to these hearings, further studies are made to establish the facts and determine that pollution exists in violation of the provisions of the Compact.

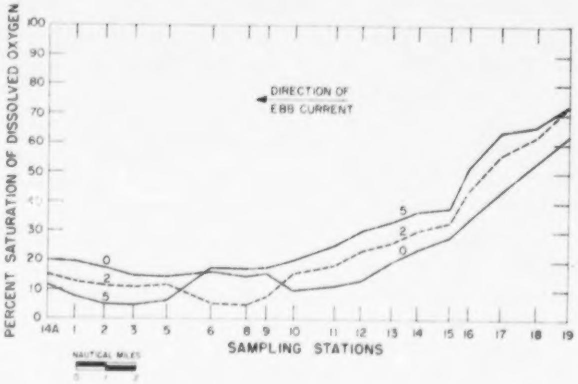

Figure 17. OBSERVED HOURLY VARIATIONS OF PERCENT SATURATION OF DISSOLVED OXYGEN, EBB CURRENT PHASE, 1959 EAST RIVER SURVEY.

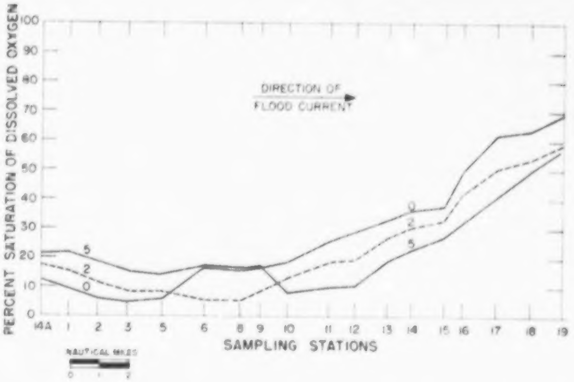

Figure 18. OBSERVED HOURLY VARIATIONS OF PER CENT SATURATION OF DISSOLVED OXYGEN, FLOOD CURRENT PHASE, 1959 EAST RIVER SURVEY.

Continuous sampling devices for water areas will provide the information not only as an aid to determine the amount of treatment needed by communities and existing industries in the areas but for additional industries in the future. This continuous monitoring also would be of great value in detecting bypassing of treatment plants or any other large source of pollution. In some cases, it may be proper to use some type of device that is less than continuous sampling. This instrument may pick up samples periodically throughout the day for analysis later in the laboratory.

In determining the facts on a community or treatment plant that is not meeting Compact standards, a portable continuous sampling device would be of great value if it were installed at such a plant for a period of several days. This would be an application of a continuous sampling device which is quite different from the previous use for water area surveys.

Our Commission could make good use of some device or type of instrumentation less complicated than the continuous sampling type that could be used by our field men for routine plant sampling. Several ideas are now being considered for such sampling.

In conclusion, we believe that state and interstate control agencies can make excellent use of water quality data if the data is properly obtained. Control agencies cannot sit back and try and administer their standards arbitrarily without having a good knowledge of the conditions of their area. Therefore, we believe the control agencies must spend a certain amount of time on applied research of their particular area. This requires an extensive survey of their water areas which may be divided into sub-areas based on local conditions. This may be followed by the location of continuous sampling equipment at strategic locations throughout the area under their jurisdiction. Even with continuous sampling, an intensive survey may be necessary after major changes of pollution abatement have occurred in a particular case. A pollution abatement and control program based on such facts will bring about cooperation by municipalities and industries.

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3. 1959 Annual Report of Interstate Sanitation Commission. "Upper New York Harbor Survey" 17-30
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A NEW LOOK AT WATER QUALITY DATA

HARVEY O. BANKS, Director, and MEYER KRAMSKY, Principal Hydraulic Engineer
State of California Department of Water Resources

When I first read the announcement for this symposium, I was impressed by the fact that this gathering represents something new in the field of water quality. To my knowledge, this is the first time that the collection and utilization of water quality data are being examined and discussed on a nationwide basis by representatives of such a diversity of interests and activities. Particularly unique is this panel discussion on "Use of Water Quality Data"; and the United States Public Health Service is to be congratulated for sponsoring this new look at water quality data.

There are many deficiencies in our knowledge of wastes, their composition, their treatment, and their effects on water resources. New technological processes are continually being developed, resulting in the discharge of strange, complex compounds that are long-lived and potent, and not appreciably affected by conventional waste treatment processes. The widespread use of detergents has created problems that have not as yet been fully evaluated, let alone solved. Highly toxic insecticides, weedicides, and other agricultural chemicals that are being applied to farm lands eventually appear in watercourses or in ground waters with unpredictable consequences. The ever-increasing volume of radioactive wastes represents a potential problem that may ultimately outweigh all others in magnitude, complexity, and severity. The potency of some of these exotic compounds requires that techniques be developed for their detection and evaluation in trace concentrations as soon as possible. It is also necessary that parameters be developed to enable the detection of the subtler aspects of pollution, such as effects on the fish-life food chain, during incipient stages. Concurrent with the growing complexity in composition of wastes are the increasing volumes that are being generated. The disposal of these wastes which result from increased use of water supplies, requires larger volumes of water for dilution, thus setting up a chain reaction in which waste disposal competes with other water demands for our dwindling uncommitted water resources. The reuse of these dilution waters requires more data regarding associated health hazards, particularly as related to viruses. A better understanding of the effects of nutrients of waste origin on the biota, particularly algal growths, is required. The reuse of water increases its mineral content, and requires more precise knowledge of allowable tolerances for municipal and irrigation use. The need for additional research in these fields is obvious; and, of course, is nowhere better appreciated than here at the Sanitary Engineering Center where many of these problems are being attacked.

These gaps in knowledge of wastes and their effects on water utilization are paralleled, if not exceeded, by deficiencies in basic data regarding the quality of our water resources. Water quality data are now collected largely on a scattered, sporadic basis; and are usually limited to specific items for specific purposes in areas where water quality problems exist or impend. Comprehensive water quality data and information are seldom available; and, as a consequence, water quality factors are often largely neglected or inadequately considered in water supply planning and management.

WATER QUALITY ASPECTS OF WATER DEVELOPMENT

It is my purpose, in this presentation, to examine the relationship between water quality and water resources development from the viewpoint of a water development engineer. In particular, I would like to discuss a few of the water quality problems involved and the water quality data required for comprehensive planning and management of water resources.

A continuing knowledge of existing conditions and changes with respect to water quality is necessary and fundamental to effective water resources planning and management. Data regarding mineral, biological, bacteriological, and radiological factors must be collected on a comprehensive, continuing basis to determine basic water quality characteristics. The effect on water quality of such factors as precipitation, stream flow, cultural development, waste disposal and drainage must be evaluated. From these data, the suitability of water resources for present or proposed beneficial uses can be appraised; and a "base line" established from which water quality trends can be noted and related to water utilization and waste disposal practices. To reiterate, adequate water quality data are as essential to efficient utilization of water resources as data regarding the quantity of water.

The need for continuing, comprehensive data regarding quality of ground waters is fully as urgent, if not more so, than for surface waters. In addition to evaluating the present quality of ground waters, there must be better knowledge and appreciation of the factors that influence and affect ground water quality. The movement of wastes within a ground water body, its diffusion characteristics, and its assimilative capacity must be determined for proper water quality management. Such factors as ion exchange phenomena and mineral pickup of percolating waters must be understood. Data must be adequate to evaluate and predict water quality problems resulting from sea-water intrusion, adverse salt balance, or faulty well construction or abandonment practices.

As water supply requirements increase and water resources development intensifies, water quality considerations become major factors in project design and operation. Present and future quality of project waters must be determined; sources of degradation delineated; and provisions for protection of water quality incorporated into project planning, construction, and operation. The volume and character of wastes resulting from water use must be evaluated; and plans for proper waste disposal must go hand in hand with plans for water utilization. The adequacy of flows for waste dilution and assimilation must be taken into account in reservoir operation studies; and the effect of wastes on water quality must be carefully assessed. The possibility of reclaiming waste waters for beneficial uses should not be overlooked in plans for water development.

A comprehensive water quality plan is an essential adjunct to long-range planning for multi-purpose development of water resources on a regional or statewide basis. Water quality requirements for proposed uses must be established and compared with projected water quality conditions. Plans for disposal of wastes must be developed and coordinated with plans for maintenance of water quality levels. Potential drainage problems should be delineated, and their effect on water quality assessed. A prime requisite to evaluation of such basic planning considerations as waste loading, dilution factors, and waste assimilation capacity is the availability of continuing, comprehensive water quality data.

The growing competition between waste disposal and other uses for our limited water resources raises questions regarding economic aspects of water quality. It must be recognized that waste disposal is a necessary use of water. Thus, in order to obtain optimum utilization of a water resource, it may be necessary to compare the economics of its use for waste disposal with the value of water quality as related to other uses. There are aspects of this problem that are not susceptible to economic analysis, and cannot be expressed in a benefit-cost ratio. However, a determination of cost should be made for various degrees of waste treatment and compared with determinable costs associated with resulting changes in water quality conditions. In this manner, a measure of the costs attributable to intangible benefits can be obtained and utilized in balancing these fundamentally divergent considerations. Where the cost of providing the tangible benefits, and the aesthetic and other intangible benefits associated with high water quality is relatively high with respect to the benefits to be obtained it is conceivable that waste disposal may represent the most beneficial use of a water course or a reach thereof.

Water rights aspects of water quality and waste disposal have not been clearly enunciated, at least not to the extent and precision that rights for other uses have been defined. It appears inevitable that, as water quality deteriorates and interferes with established uses of water, litigation regarding water quality will increase in frequency and magnitude; and water quality rights will, of necessity, achieve recognition and definition. As in other water rights procedures, reliable historic water quality data will probably be essential for equitable determination of water quality rights. Adjudication of water quality rights may hinge upon resolution of such factors as natural water quality conditions and fluctuations, water quality requirements, identification of sources of degradation and influence of each, chronology of water utilization and waste disposal, and relative benefits of waste disposal and water quality. It is conceivable that, under certain conditions, rights to the use of water for other purposes may be limited by waste disposal considerations.

WATER QUALITY ACTIVITIES OF CALIFORNIA DEPARTMENT OF WATER RESOURCES

The State of California has long been cognizant of the importance of conserving and protecting its water resources; and, with respect to water pollution, generally follows the maxim - "An ounce of prevention is worth a pound of cure." A number of state agencies conduct water quality activities in the discharge of their assigned responsibilities, including the Department of Fish and Game, Department of Public Health, and State and Regional Water Pollution Control Boards. Each of these agencies has direct regulatory responsibilities for prevention of water pollution*, contamination*, or nuisance*. However, I would like to discuss the water quality activities of the Department of Water Resources as an example of how water quality data are collected and utilized in California, although that Department does not have such regulatory responsibilities.

The Department of Water Resources has broad responsibilities for the development, conservation, and protection of the water resources of the State. In discharging these responsibilities, the department conducts studies of water supply and utilization, investigates water quality conditions, formulates plans for water development, and constructs and operates water projects. In each of these activities, water quality considerations constitute an essential element.

In cooperation with other agencies, surface and ground waters are sampled regularly at a network of stations throughout the State, as part of a continuing water quality surveillance program. Mineral, biochemical, biological, and radiological characteristics are determined and correlated with hydrology, geology, and cultural development. Trends are noted, and probable causes ascertained. Where existing or potential water quality problems are indicated by these surveillance programs, detailed studies are conducted by the department to evaluate the sources of water quality impairment; recommendations for remedial measures are formulated; and appropriate regulatory agencies are notified.

One of the recognized causes for degradation of ground water quality is improperly constructed, abandoned, or defective wells. Ground waters constitute a major source of water supply for California, and the protection of ground water quality is essential to the economy of the State. There are no statewide regulations for water well construction or abandonment, but the department conducts studies and formulates recommendations regarding standards necessary to protect ground water quality. These recommendations are based on evaluation of ground water geology, hydrology, and water quality; and deal with well location, type of construction, type and placement of seals, and treatment of abandoned wells.

The responsibility for control and regulation of waste discharges in California is vested in regional water pollution control boards. These boards establish requirements and regulations to govern the discharge of wastes, so designed as to protect receiving waters from pollution and maintain their suitability for beneficial uses. The department provides advice and assistance to these boards regarding factors to be considered in setting waste discharge requirements. Information is furnished on water supply, water quality, beneficial water uses, water rights, plans for future development, and known or suspected pollution hazards. The potential effect of the waste discharge under consideration upon surface and ground waters is evaluated. In addition, special studies are conducted to furnish information on water quality conditions and to assist boards in formulating long-range water pollution control plans.

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*The California Water Code defines pollution as: ". . . an impairment of the quality of the waters of the State by sewage or industrial waste to a degree which does not create an actual hazard to the public health but which does adversely and unreasonably affect such waters for domestic, industrial, agricultural, navigational, recreational or other beneficial use, . . ."; contamination is defined as: ". . . an impairment of the quality of the waters of the State by sewage or industrial waste to a degree which creates an actual hazard to the public health through poisoning or through the spread of disease."; and nuisance is defined as: ". . . damage to any community by odors or unsightliness resulting from unreasonable practices in the disposal of sewage or industrial wastes".

The importance of reclaiming and utilizing waste waters wherever possible is recognized by the department in formulating plans for development of water resources of the State. In order to evaluate the practicability of waste water reclamation, major waste discharges are catalogued, quantity and quality characteristics are determined, and feasibility studies are conducted to determine costs, methods, and possible uses of the water to be reclaimed.

Studies are conducted to evaluate the water quality aspects of proposed water development projects. The quality of project source waters is determined, and its suitability for anticipated uses is ascertained. Salt-routing studies are made to examine the possibility of undesirable mineral accretions occurring in the proposed area of use. The potential degradation that might result from waste waters in the service area is evaluated.

The Sacramento River is of paramount importance to the economy of the State. It serves as a water resource, a fishery, a source of hydro-electric power, a waterway, and a conveyance system for imported waters as well as releases from upstream reservoirs. It also provides a means for disposal of municipal, industrial, and agricultural wastes originating in the Sacramento Valley.

A comprehensive study is being conducted by the Department of Water Resources to delineate present and future water quality conditions in the river, to evaluate all the factors that influence water quality, and to provide guides for water quality management, particularly with respect to statewide water development plans. This study involves the determination of physical, chemical, biological, and sanitary aspects of water quality under various flow conditions; and includes evaluation of quantity and quality of wastes, return irrigation flow, and tributary drainage. Biochemical relationships will be established, and the aquatic population catalogued. The waste assimilation characteristics of the river will be computed and compared with estimated waste discharges under projected conditions of development. This study will serve to establish a base line from which future changes in water quality can be determined; and it is designed to provide information for all agencies with water quality responsibilities or interests. It will be utilized in formulating plans for drainage and waste disposal; and in coordinating these plans with water quality requirements for proposed water supply projects. In furtherance of this concept, the study is being planned and conducted by the department in collaboration with the Central Valley Regional Water Pollution Control Board, the State Department of Fish and Game, the State Department of Public Health, and the United States Public Health Service, with the aid and assistance of other agencies.

The Sacramento-San Joaquin Delta is an example of an estuary where water quality considerations are particularly involved. The delta is used as a source of water supply by several communities and many industries; and it provides water for an extensive irrigation development. It supports very important fishery resources and provides recreational opportunities for a considerable portion of the State's population. It also serves as a transfer point for the United States Bureau of Reclamation's Central Valley Project, which diverts fresh water from the delta and conveys it to the San Joaquin Valley. Additional diversions will be made under the Feather River and Delta Diversion Projects to be constructed by the State of California. Water quality in the delta is subject to many sources of degradation. In common with all tidal estuaries, it is subject to incursion of saline water from the ocean. It receives industrial and municipal wastes from contiguous lands, together with drainage and return irrigation flows, and large amounts of waste heat from industrial cooling water return. Furthermore, the San Joaquin River, which forms the southern arm of the delta, contributes considerable quantities of highly mineralized drainage waters during the irrigation season.

Plans for future water development in California contemplate greatly increased use of the delta for collection and diversion of surplus waters from the north to areas of deficiency in Southern California, the San Joaquin Valley, and coastal areas. An essential factor in formulation of these plans is an accurate evaluation of all water quality aspects to assure that water will not be degraded in transit across the delta, to determine the necessary protective and waste disposal facilities required, and to evaluate the possible effects of this project on the quality of waters in San Francisco Bay, where some serious water pollution problems still exist. The advisability of constructing a model to evaluate the hydraulics and water quality problems in the delta is under consideration. It is possible that an existing model of San Francisco Bay, which has been developed by the Corps of Engineers, could be extended to reproduce and study flow phenomena in the entire estuary; and thus form a basis for predicting water quality conditions and establishing operating criteria.

The Department of Water Resources is also developing plans for a master drain to collect and remove saline drainage waters and other waste waters from the westerly and southerly portions of the San Joaquin Valley to a point of safe disposal in the San Francisco Bay system. Such a drain is necessary not only to maintain the productivity of the agricultural lands concerned but also to protect the quality of the water resources involved, including those of the Sacramento-San Joaquin Delta.

Studies are being conducted to formulate definitive, long-range plans for optimum utilization and management of the ground water basins of Southern California. These studies envision the use of underground reservoirs for storage and distribution of imported water supplies, in addition to conservation of local water resources. Geologic, hydrologic, and hydraulic factors are being evaluated to determine recharge rates, storage capacity, and aquifer transmissibility; and full consideration is being given to legal, financial, and economic aspects. An essential prerequisite to effective ground water management is maintenance of suitable water quality; and considerable emphasis is being placed on such water quality considerations as salt balance, intrusion of sea water, migration of connate brines and other waters of poor quality, disposal of wastes, successive re-use of waters in interconnected ground water basins, and utilization of reclaimed waste waters for ground water recharge.

It is contemplated that contracts for water to be supplied by the Department of Water Resources under the State's water development program will include provisions with respect to water quality. These stipulations will be based on long-range estimates of water quality anticipated under future conditions of water development. In furtherance of this concept, a comprehensive statewide water quality plan will be formulated to establish water quality conditions required for optimum development and management of the waters of the State. Water quality conditions that must be maintained in the Sacramento-San Joaquin Delta have already been enunciated, as shown in the following table; and now serve as a guide for regulation and control of waste discharges to tributary waters.

WATER QUALITY LIMITS FOR WATER FOR EXPORT AT POINTS OF DIVERSION AT SOUTHERN BOUNDARY OF SACRAMENTO-SAN JOAQUIN DELTA

Item	Limit
Total Dissolved Solids	400 ppm
Electrical Conductions (Ec x 10^6 at 25° C)	600
Hardness as $CaCO_3$	160 ppm
Sodium Percentage	50%
Sulfate	100 ppm
Chloride	100 ppm
Fluoride	1.0 ppm
Boron	0.5 ppm
pH Value	7.0-8.5
Color	10 ppm
Other constituents as to which the U. S. Public Health Service has or may establish mandatory or recommended standards for drinking water	USPHS Limits

These conditions, in essence, already constitute an element of a statewide water quality plan. Long-range plans for regulation and disposal of wastes, based on projections of land and water use, estimates of wastes generated, and plans for modification or control of stream flow, constitute additional elements of water quality planning. In addition to providing a basis for establishing water supply specifications, such water quality planning will serve as a guide to water pollution control boards in setting waste discharge requirements. Public Health, fishery, and recreational aspects must also be incorporated to assist those interests in the discharge of their responsibilities. A comprehensive long-range water quality plan which reconciles all of these diverse interests will be of inestimable value to both water users and waste dischargers, in that it will constitute a basis for advance planning of their operations and installations.

CONCLUSIONS

There is a growing awareness of the need for taking a new look at water quality data from the standpoint of types and adequacy of data collected, frequency of sampling, continuity of records, extent of coverage, and utilization of information, particularly its incorporation into plans for water resources development and the implementation of such plans. The growing competition between waste water disposal and other uses for our limited water resources requires that water quality data be collected on a continuous, comprehensive basis comparable to stream flow, precipitation, and other traditional hydrologic data.

As waste discharges increase in volume and complexity, and water quality approaches marginal conditions, reliable criteria must be established to cover the water quality aspects of water development. Economic factors will assume greater significance; and a body of law must be established regarding water quality rights, comparable to laws governing quantitative rights to water use.

A program for collection of water quality data should be designed to meet requirements for all purposes, including public health, water resources development, water pollution control, recreation, and fishery. It should be responsive to the needs of all agencies with responsibilities for water resources management; and should preferably be the responsibility of one agency, in the interests of efficiency and economy. Other interests should participate in advisory and complementary capacities; and the data should be made readily available to all. However, collection of water quality data should not become an end unto itself. Only to the extent that these data are utilized in water resources development and management do they serve a useful purpose.

The national monitoring network of the United States Public Health Service could well serve as a model and primary control system for secondary statewide networks. However, it is felt that serious consideration should be given to combining this network with the data collection program of the United States Geological Survey to form a unified, comprehensive nation-wide water quality sampling network. This network, which should concentrate largely on interstate waters, could serve as a guide and model for state and local networks by setting standards for collection and analysis of samples, by establishing criteria regarding types of data and location of stations, and by developing methods for interpretation and utilization of data obtained. The Federal Government could play an important role in encouraging the development and establishment of these statewide secondary networks. addition to operating the national monitoring network as a model and control system, federal agencies could provide technical assistance and research in setting up local systems and demonstrating the need for and utilization of water quality data. In order to encourage the collection of adequate water quality data on a comprehensive, systematic basis, the Federal Government might well participate in the establishment and operation of local programs by providing financial assistance. Funds for local data collection networks could be included in the federal water pollution control program, in recognition of the national interest in adequate collection and utilization of water quality data for development and management of our water resources.

Water quality considerations constitute an essential element in the utilization, conservation, and development of water resources; and should be rigorously evaluated for present and projected future conditions. Water quality planning should be conducted in conjunction with water development planning on a region-wide scale, in order to achieve optimum development of water resources on an orderly basis. Long-range plans for regulation and disposal of wastes should be incorporated in water quality planning, as should public health and other appropriate considerations. A comprehensive, long-range water quality plan is essential to coordinate all competitive water uses; to provide a basis for sound, economic waste disposal, and to provide water users with authoritative prognostications of water quality conditions.

HIGH QUALITY WATER WITHOUT HIGH QUALITY DATA - IS IT POSSIBLE?

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In this discussion high quality will refer both to purity in the sense of absence of pathogenic organisms, and those quality considerations which have to do with taste, odor, color, hardness, and similar characteristics. The paper will concern itself primarily with water sources from surface streams, and particularly those streams which are used for disposal of sewage and industrial wastes, both treated and untreated.

The problem of water quality is a fluid and changeable one. In those communities which originally used wells, the pollution which reached the wells often caused the community to go to a surface stream. In Philadelphia this happened as far back as 1799. From the standpoint of health, and of taste and odor, the resultant product was far below the quality which we turn out today, even granted that the streams were not badly polluted at that time.

Succeeding generations demanded water of a higher quality, and this was especially so where public health and water officials had shown that disease organisms existed in water, and that these organisms could be removed. The same thing applied to taste and odor. As a result from time to time new procedures were installed, beginning with simple sedimentation, and Philadelphia has now reached the stage where we are completing the second set of filter plants.

We would be brash to assume that some time in the near future scientists and engineers will not discover in water the existence of pathogenic organisms of some type which have not been isolated at this time. Since there has been an increasing demand for better quality in practically all things used by citizens, they will equally demand better tasting water, or at least water from which objectionable tastes and odors have been entirely removed.

Modern water treatment plants can provide facilities for the production of water which is free from disease, at least as far as we know it today, and which is readily acceptable as to taste and odor. These treatment facilities include all of the well known mechanical aspects of sedimentation, mixing, and filtration, the addition of many chemicals as part of the treatment process, sterilization, and the addition of other chemicals for such purposes as fluoridation and corrosion inhibition, and for changes to assist in the treatment process. In all of these things it can be truly said of the type of water which is under discussion that it is a manufactured product.

Quality control is certainly not a new subject. It ranges all the way from the chef in the kitchen tasting the soup, to the highly complex mixtures in the chemical and metal industries which produce the products which we need today.

In most of these manufacturing processes, the emphasis is on the continued maintenance of high quality. One bad kettle of soup may drive away customers from a restaurant who will not return, and one bad batch of steel may cause a failure in the member of which it finally becomes a part.

In the water industry we have been somewhat alert in later years as far as the healthful condition of the water is concerned. Chlorination destroys pathogenic organisms, or at least it destroys those of which we have knowledge.

In many instances, however, we have not been as alert on the matter of taste and odor quality. It is not unusual to have raw water samples taken every 3 or 6 hours, and perhaps less frequently during night time. If during this period some slug of chemical waste reaches the intake, or the washdown from some decaying vegetation reaches the plant, water of this source may go through the treatment processes, getting the same treatment that raw water of a different quality was receiving. It is not even beyond the realm of possibility that poisonous substances might enter the plant without the immediate knowledge of the operator.

Some measure of procedures at modern filter plants can be seen from a recital of the testing work at the new Philadelphia Torresdale plant on the Delaware River. Tests such as turbidity, alkalinity, and pH are made every 3 hours. Most of these tests are either automatic or can be accomplished in less than 10 minutes. Taste and odor tests are run 3 times in 24 hours, with these tests taking perhaps 10 or 15 minutes to accomplish. Other tests such as hardness, chlorides, nitrates, phosphates, manganese, and iron are run only once a week. Several of these tests take more than one hour to perform.

In addition to the normal tests which are required in order to produce high quality water, many water plants in industrial areas are faced with the problem of accidental spills of dangerous and poisonous chemicals. Within the last 10 years, the Philadelphia Torresdale plant has had two such spills which involved a cyanide compound. In one of these instances more than 2200 pounds of acetone cyanhydrin were spilled into the river about five miles upstream from the water plant intake. In recent months an accidental discharge of endrin, an insecticide, caused serious trouble and concern. Where such upstream hazards are known to exist, automatic information on such spills would be of value to the water plant operator.

Modern plants such as Torresdale, which was placed in operation late last year, have complete automatic facilities for chemical application and for other operations in the plant, including washing of filters. When the chemist sets the ratio of chemical application, the chemicals are fed in the proper amount with automatic adjustments being made as the ratio of flow varies. With this type of equipment you can be assured that the water is receiving the treatment which the chemist decides upon.

But, having once set the ratio of application, there is no change until samples of raw water and samples from water throughout the plant are carried or piped to the laboratory and tested. This is the point at which variances in quality of final water can occur.

It is suggested that if data on the quality of water were available immediately and at all times, the plant chemist could make the necessary adjustments as the quality of the raw water and of the finished water changed. With automatic feed of chemicals, his decisions could be transmitted immediately to the various points of application and treatment. Such an operation would require instruments which would report immediately on those characteristics of the water which must be known in order to give proper treatment.

Some of these instruments might have to be located at distances away from the plant. This would especially include those which would sample raw water conditions in a river such as dissolved oxygen, B.O.D., and evidence of the phenol pollution which is the bane of existence of most water works operators in industrial areas.

The second step in automation would require that the readings on these instruments be transmitted in some manner to the laboratory for the immediate knowledge of the chemist. For those readings which are within the plant area, ordinary telephone lines would be sufficient. For much longer distances on the river, the same type of telephone wires could be used, and in some cases it might be desirable to use a microwave system.

With all of the information in front of him, the plant chemist should be able to adjust his treatment procedures minute by minute if necessary, and to have the proper amount of chemicals fed automatically as he makes his decisions. Since many of the combinations would be routine, the decision would not need the presence of a high level chemist, but merely one who would be trained to observe the proper readings and to do those things which were already decided for him.

The next step beyond this would be the ultimate in automatic controls. If the equipment included a digital computer into whose memory had been stored all possible combinations of raw water data, and the treatment which was required when any such combination was present, the computer could automatically send to the chemical plant, without the intervention of the chemist, the necessary information concerning chemical dosage, and other treatment procedure. Once in a while, perhaps, a combination would occur which would not be stored within the memory of the computer, but this circumstance would ring a bell, light a light, and wake up the shift chemist on duty who would either make a decision himself, or call for help if the situation were unusual.

All of this may sound fantastic, but it should not be so to anyone who has observed what is being done in the field of instruments and automation. A short review of what has been done in Philadelphia along the Delaware River may point out how far we are advanced in this type of thinking.

Along the upper Delaware, the Lehigh Water Resources Research Council, working for INCODEL, is in the process of developing and installing automatic machines for monitoring water quality. At the present time a station on the bridge at Riegelsville is taking automatic samples which record temperature, pH, conductivity, sunlight intensity, turbidity, and dissolved oxygen. For a full report of this work see Proceedings Paper No. 2554 of the Journal of the Sanitary Engineering Division, ASCE, Vol. 86, SA4, July 1960.

The Philadelphia Water Department has been interested enough in the matter of automatic instruments for quality measurements that it has installed several such instruments on the Delaware River, and is planning to install others on the Delaware and on the Schuylkill River. Most of this work has been done as a joint venture with the U. S. Geological Survey. Within the last two months, continuous instrumentation for dissolved oxygen, temperature, and specific conductance, has been installed on the Delaware, a few miles below the Torresdale water plant, but at a point which is within the tidal influence at the plant. In October of this year, the installation of instruments will be completed at Trenton, upstream from the Torresdale plant, which will measure pH, specific conductance, temperature, turbidity, and dissolved oxygen.

Similar installations covering one or more of these parameters are scheduled for the next 18 months at various points on the two rivers which furnish water supply for Philadelphia. All of these are of the type in which the data are continuously recorded on charts which have to be picked up from time to time.

Automatic monitoring equipment for measurement of radioactivity has been purchased and is now undergoing tests. This equipment will record radioactivity on the Delaware and Schuylkill Rivers. The Philadelphia Water Department is assisting ORSANCO by helping to test and operate experimental equipment for the continuous measurement of phenols.

Instrument makers are becoming aware of the need for automatic instruments of this type in the water industry and related industries. One manufacturer has a list of instruments which will provide for continuous measurement of 50 water qualities and related variables. These 50 are in some stage of development, ranging all the way from complete instruments to those which are in the development stage. At least 14 other variables are under discussion and review. Needless to say, these 14 include some of the really difficult measurements, such as ammonia nitrogen, chlorine demand, coliform organisms, and B.O.D. This paper will not discuss these instruments in detail, since this subject will be treated at much greater length by other papers delivered at this symposium.

On the matter of transmitting the data from the instrument to a central point, there is so much that has been done that this phase should produce only minor problems. Using Philadelphia as an example again, there has just been placed in operation a load control center which handles quantity, pressure, height, and other hydraulic elements of water supply. Information from the various gauges and instruments scattered throughout the City is transmitted through a system of land wires and microwave stations to a central point. At this point the information is decoded and typed out on a typewriter. Transmission and typing of this information is done at the rate of one station per second, and the scanning of the system for faults is done at the rate of four stations per second. There should be little trouble in transmitting quality information to and from a central point, if we can get the instruments and measuring devices to automatically measure the parameters which are desirable.

Beyond all of this are two basic problems: The first problem is the willingness of those in the water works industry to decide that this type of automatic operation is necessary, and to take all the steps required to bring it to fruition. The second is to provide the economic justification for the funds which will have to be expended to do this kind of work.

This symposium at Cincinnati will be of real help in encouraging those present and those back home to give serious thought to the need for the various instruments and equipment which will be needed. It will take an evidence of interest by a substantial number of water works people to induce laboratories, universities, research centers, and manufacturers to put the time and money into the development of this equipment.

Economic justification is a somewhat different problem. In working on the improvement of the water works of Philadelphia, it was not too difficult to justify the renewal of an old pump if it could be shown that the power savings were more than the carrying charges on the cost of the new pump. Justification for quality in terms of dollars and cents is another thing. If people are receiving poor water, in most cases they might be willing to pay an increased cost to get better water, although the measurement of such benefit is almost impossible. The problem becomes more difficult if we try to take a system which now produces good water and hope to turn out excellent quality water by the use of the equipment suggested by this paper.

Philadelphia faced somewhat the same problem with its load control center. It was certainly a great improvement to be able to get practically instantaneous information on all phases of the system, as compared to the old method of a few telemeter gauges and telephone reports. However, we were faced with the comment that if we got along without the new gadget in the past, why can't we get along with the same equipment for the future and save the capital cost of new equipment. We answered that by installing with the load control center a supervisory control system for remote pumping stations, which has permitted the removal of operators from these stations. The saving alone from this procedure accounts for far more than the carrying charges on the new equipment, but we also get the bonus of having better information available, and available at once.

This might be the economic approach to automatic quality control of water. It would seem that such instrumentation could be better justified in a large water works system, and one which had difficult and changing characteristics in raw water. The real savings, however, could readily be in reduced laboratory personnel and in field and operating personnel.

I am sure that if those of us who are operators are willing to point out the requirements and the benefits, we will find men in the instrument field who will develop the needed equipment, and we will be able to justify the necessary costs.

SOME OBSERVATIONS
ON THE
ADVANTAGES OF SUSTAINED WATER QUALITY DATA
TO PRIVATE INDUSTRY

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Throughout the industrial history of this country, water has been a cheap service commodity, generally free to use with modest extraction cost. In the past, except for certain arid districts, it has usually been abundant in supply and, at least, moderately satisfactory in quality.

Continuing technological advances during the past half century in equipment design, process improvement and product development have placed more critical demands on service water quality and availability. Although the availability factor has only occasionally become a problem, the raw water quality tends to deteriorate, because of pollution, in proportion to our urban and industrial development. Fortunately, through the efforts of Governmental agencies of all levels, public-spirited citizens and a host of organizations, this latter problem appears to be partially arrested. Nevertheless, it has increased the cost of water conditioning and effected decisions on treatment standards, as well as adding great volumes of water to the treatment load that normally were not there.

During the past quarter century, the accelerated spiral of higher wages, more fringe benefits, higher costs of equipment and materials, as well as higher taxes, necessitated greater output and higher efficiencies per production unit. To a large extent, this economic pressure was relieved through further technological developments. In many instances, this meant higher skin temperatures or more critical tolerances which, in turn, were and are being reflected in water quality requirements.

It is this historical background which demonstrates the economic, operational and physical needs for sustained basic water data in industry.

A DISCUSSION OF VALUES

A subject much bandied in literature and lecture is the economics of industrial water treatment. The logical approach of a responsible water conditioning operator or plant services chief is relative, primarily related to equipment, material and operating costs, perhaps to his own experiences or to the operations of others in the field.

In contrast, a recent authoritative article on water resources has placed service or process water on a nearly infinitesimal plane, relative to the cost of production.

Obviously, both approaches to the economic problem are not the same and each has its merit in its own realm. Water conditioning, as such, rarely comprises more than a very minor portion of production costs as a direct charge. However, as an over-all cost, it could become major in proportions. Equipment failure due to water quality can be expensive, whether viewed from the replacement angle or the loss in production.

Probably the most costly loss has no price tag. The critical nature of water quality to many processes has never been adequately established, primarily because it is assumed to be a cheap service, performing as such. Closer tolerances, ease of manufacture, higher quality and lower reject percentages are the gain of many manufacturers who recognize the importance of precisely controlled water quality. This all relates back to the need for a well-organized sustained water data program, both before and after conditioning.

It also relates to the physical needs of sustained water data. The multiplicity of process uses, compounded throughout the years, creates a chaotic picture which perhaps only the water services operator can understand. He finds himself retreating or adjusting his conditioned water for specific applications throughout the plant, at best a compromise, and subject to the vagaries of raw water supply and treatment plant deficiencies or malfunction. A well-organized sustained data program can, not only point out areas of inadequate control but, also serve as a sales aid in obtaining appropriations for suitable equipment or additional capacity.

The operational values of a sustained data program, although deeply involved in the intricacies of plant water use, can probably be concentrated to a simple general statement. Logically, it is easier to determine where you are going, if you know where you are and where you have been. Fundamentally, this is the prime reason for sustained basic data. The lack of such basic water knowledge could be likened to driving a car without ever using the rear view mirror.

ITEMS OF SUSTAINED DATA

To define the items necessary in a sustained data program for industrial water would require running the gamut of water knowledge from end to end. As a process tool, it may be used in producing or transmitting energy, to segregate, dissolve, clean, cool, heat, transport, disperse or an almost infinite number of related applications. When used as a raw material, it may emerge as part of the product. In addition to these uses are the basic quantities used for sanitation and fire protection.

Obviously, the control items for basic industrial water data must depend on the plant water uses, the relative importance of each water characteristic to these uses and the comparative natural variability of these items. Realistically, there are no allowances in a profit-making enterprise for the collection of abstract or unrelated data, so these data must be kept to a minimum of indicative items.

The selection of these items may be based on a number of ultimate purposes, the most obvious of which are:

1. For water plant operational assistance.
2. For investigative use in water plant operations and factory applications.
3. As a means of substantiation to Management for appropriations.
4. As an historical record on which to base future planning.

A DISCUSSION OF PURPOSES

In the normal operation of water treatment facilities for any purpose, it is desirable to determine normal seasonal fluctuations of the water supply, the rapidity with which they occur and the range through which they deviate. The frequency of unseasonal deviations can be recorded, and unaccountable variations may possibly be traced to their source. Dependent upon this basic data could be the current seasonal inventory of raw materials, the manpower schedule, the maintenance and overhaul program and, even the vacation schedule. After considerable experience under stable load conditions, it is not unusual to predict treatment plant operating conditions by area weather report. It is rare indeed that industrial water conditioning facilities are of more than adequate design, and any reasonable clue can usually be of assistance.

The greatest industrial use of water remains in the untreated, unconditioned category. It is in this area that a sustained data program can be immensely helpful, in tracing plant process difficulties or in product quality correlation. Obviously, the demand for water of different quality, even in the same industry, changes as the processes improve or develop. In a similar vein, the volume of water necessary may vary from factory to factory within an industry relative to the quality of its water source. The changing trends of these water supplies, the scaling or corrosive characteristics, the organic inhibitors, the dissolved solids, the alkalinity, pH, the biologicals and colorants, the temperature and volume available - just to mention a few - could produce a vast change in production allocation or expansion planning. Just as our water quality changes, so do the requirements of industry in a never-ending cycle of improvement to process and product through competition.

Few, if any, water service operators in industry could approach Management with an unsubstantiated request for a capital expenditure, and this is, undoubtedly, as it should be. A simple means of substantiation lies in the collection and presentation of indicative sustained basic data, coupled with production data from the division to be serviced. Management does pay for water control and it is its reasonable expectation that the data, thus obtained, be accumulated and compiled in comprehensible form.

In this age of unparalleled economic, industrial and population expansion, almost all industry is planning for future growth. The changes of market centers are being closely watched and plans are gelled accordingly. In this realm, sustained water data, as an historical background, is invaluable. Every expert prediction indicates at least a 100% increase in the use of industrial water within the next fifteen or twenty years. Will the water be available, and in reasonable quality, when we need it? Theorizing won't help and only a widely organized basic data program can point the way. In reality, these problems are not just industrial but relate to the welfare of the public, in general. The prosperity of our communities, our farms and our nation is enmeshed with the availability and quality of our water supplies.

Pollution loading on streams has a direct bearing on the need for water conditioning, the type and design of the conditioning plant, on the investment required for the treating facilities, and the cost of their operation. Intelligent planning for expansion or the establishment of new facilities can only be accomplished by the study of historical data.

SOME PERSONAL EXPERIENCES

One of the smaller tributaries of the Mississippi is the Illinois River, originating approximately 275 miles above its mouth by the confluence of the DesPlaines and Kankakee Rivers. At about the turn of the century, the city of Chicago reversed the flow of the Chicago River by constructing the Sanitary Drainage Canal as the connecting link between the Chicago and DesPlaines Rivers. The purpose of this flow reversal was to divert sewer discharge away from Lake Michigan, the city"s prime source of drinking water.

As a result, the Illinois, a river internationally known as a fishing paradise, became virtually an open sewer. In the 1920's to the mid-1930's, not even vegetation would grow along its banks and the pollution began to spread from our mid-continent to the Gulf.

During this period, the Chicago Sanitary District took steps toward alleviating the pollution problem; the Illinois Waterway facilities were constructed by the State and Corps of U. S. Engineers, and, in the 1930's the U. S. Supreme Court restricted the diversion from Lake Michigan as dilution water to 1500 cfs.

It was at this point, that the writer received his first experience at industrial water treatment. Ottawa, Illinois is situated at the confluence of the Fox and Illinois Rivers, and this juncture is approximately one mile above the factory site. This fact alone introduced water variations subject to wind direction and velocity. In addition, although the Illinois was improving rapidly, it was subject to wide variations from run-off or other dilution sources. This precarious water source, coupled with innumerable production complaints, led to the eventual establishment of a sustained basic data program. The items of information were simple chemical determinations, originally selected to denote scaling index by Langelier formula, but broad enough in scope to relate to various critical production operations. It was soon found expedient to carry on separate programs for individual processes but, in addition to organized data, a basic comprehensible graph has been maintained throughout the years as an historical record. A series of charted averages were plotted for operational assistance and future planning.

At the outset of the data program, it was decided to avoid data not specifically needed and to make every effort to avoid items of parallel indication. Consequently, the program was initiated with the usual tests for chlorides, sulfates, hardness, pH, total dissolved solids, chlorine demand, turbidity and alkalinity, in addition to local weather data.

Throughout the years, the procedure has changed but little. Although chlorides and sulfates are still checked, they have been dropped from the sustained items, primarily because their variation was strictly a function of dilution. Chlorine demand has been dropped, except for occasional checks, in lieu of the simpler flash test. These figures, too, were found to be mostly a function of dilution, as indicated by alkalinity. Added to the list, was calcium hardness.

Graphical portrayal of some of these figures in a time series indicates the possible trends, the short term and possible long term cycles, and the magnitude of fluctuations.

Figure 19 illustrates the yearly cycle, pointing out the gradual trend of improvement. It is worthy of note that the yearly cycle was interrupted during December, 1956, through February of 1957, due to increased diversion from Lake Michigan. It is also noteworthy that extremely high turbidities have become a rarity. This is attributed to a highly efficient United States Government Soil and Water Conservation Group. A number of observations could be made that do not appear on the chart. For example, it was found in plant operations that turbidities originating in the Kankakee River were extremely difficult to clarify.

Figure 20 illustrates a slight yearly trend toward improvement, with perhaps an indication toward the beginning of a long term cycle. If time proves this to be true, it will undoubtedly be based upon a precipitation cycle.

Figure 21 is a small segment of a time series graph which, in full scale, extends to something over fifty feet in length. Originally intended for project proposals with Management, this chart has been used many times in trouble shooting and product correlation.

Since the initiation of this data program, plant water treatment facilities, which originally consisted of only crude boiler water conditioning equipment, have expanded to include new and modern boiler water conditioning, a cooling water treatment plant and a

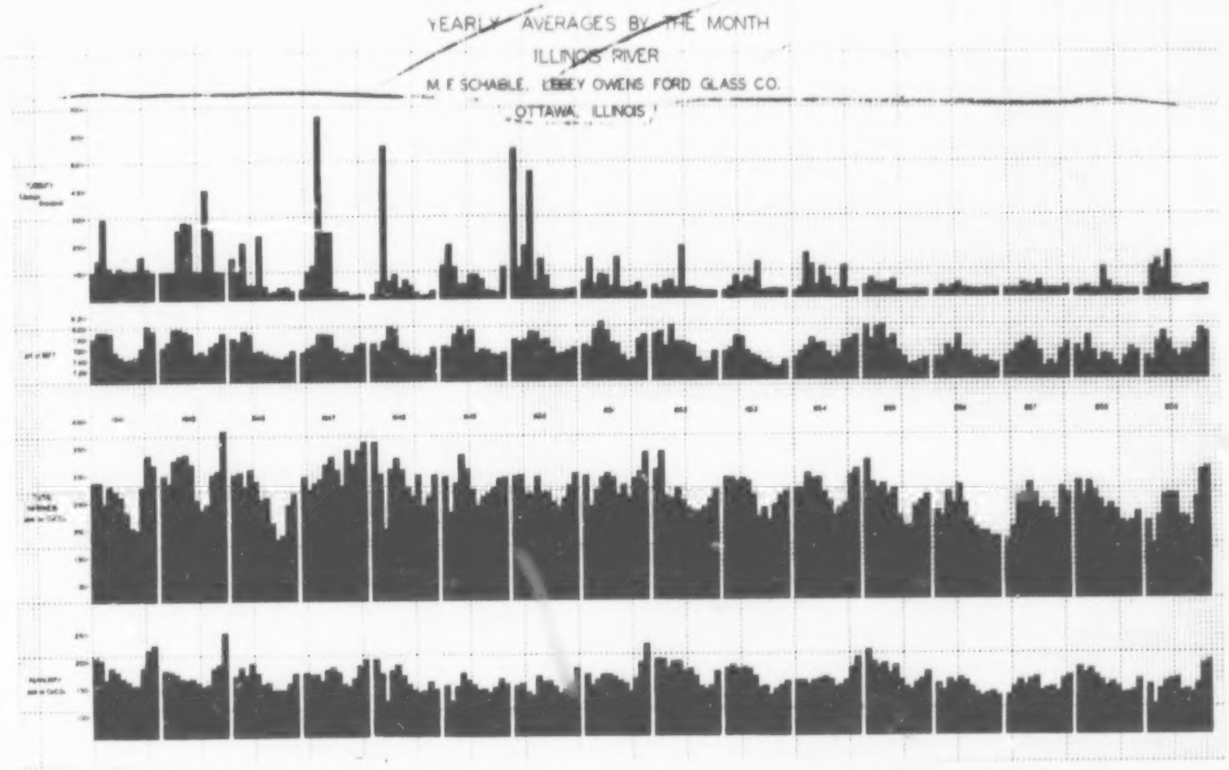

Figure 19. ILLINOIS RIVER WATER QUALITY DATA, MONTHLY AVERAGES FOR THE YEARS 1941-1959.

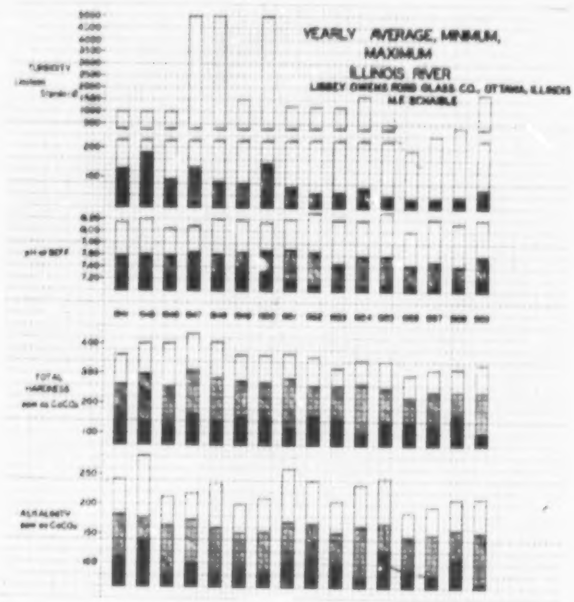

Figure 20. YEARLY AVERAGE, MINIMUM, MAXIMUM, ILLINOIS RIVER.

large general process water installation, which furnishes basic process water for retreatment or adjustment at the application, if necessary. Simple though it was, comprehensive sustained data proved a point, and process water treatment is here to stay.

As a point of clarification, it might be well to explain that, although not equal in tonnage capacity, automotive safety plate glass manufacture requires approximately the same amount of water per ton of finished product as steel - perhaps, somewhat more - and the quality requirements are generally much more critical. Much of this water is either conditioned or under process control with every previously itemized process use represented as a distinct problem.

EXISTING DATA GAPS

To cite existing gaps in basic water information for private industry would necessarily be a generalization. The selection and treatment of water is usually dissimilar for each industry, and the importance of the parameters in each location would be widely variant. To industry in general, there is no doubt that every possible parameter is a necessity. The National Water Quality Network of the U.S. Public Health Service should be of tremendous value to industry in the future. The broad scope of information, its reliability and the eventual indication of trends and ranges will be a boon to industrial planning and engineering.

Automatic instrumentation for analyses, once demanded by industry, is rapidly being solved for some determinations. Others will, no doubt, be solved as the demands increase and as applications permit. For strictly selfish reasons, the writer would like to see automatic determination of chlorine demand. Other demand determinations would undoubtedly be valuable to various industries or agencies. Analyses of gaseous components would probably be another fertile instrumentation field, as well as innumerable specific minerals. Many of these items could possibly be determined with presently designed equipment, if the needs are known.

From the standpoint of many industrial water consumers, and from municipal establishments as well, the greatest current gap in data and analytical procedure is a practical, short but reasonably accurate method for the determination of pollutant detergents. Even better would be the ways and means of their complete elimination. Although presently a problem of municipal and certain industrial water applications, it is a problem of growing intensity which, in many industrial uses, is an unknown factor of potentially great importance.

The presence of organic wastes in water is significant to industrial water treatment and uses, as well as treatment costs. Recent analytical developments by the U. S. Public Health Service appear quite indicative, but the equipment is cumbersome and the process is long, tedious and involved, too much so for standard industrial procedure.

The above statement should, in no way, be construed as criticism. On the contrary, it may be considered as tribute to a great preliminary stride toward the solution of our future National water problems.

During the past few years, most of the States have either adopted comprehensive pollution control laws or instituted programs for the regulation of pollution. Some of these laws or programs are aimed primarily or

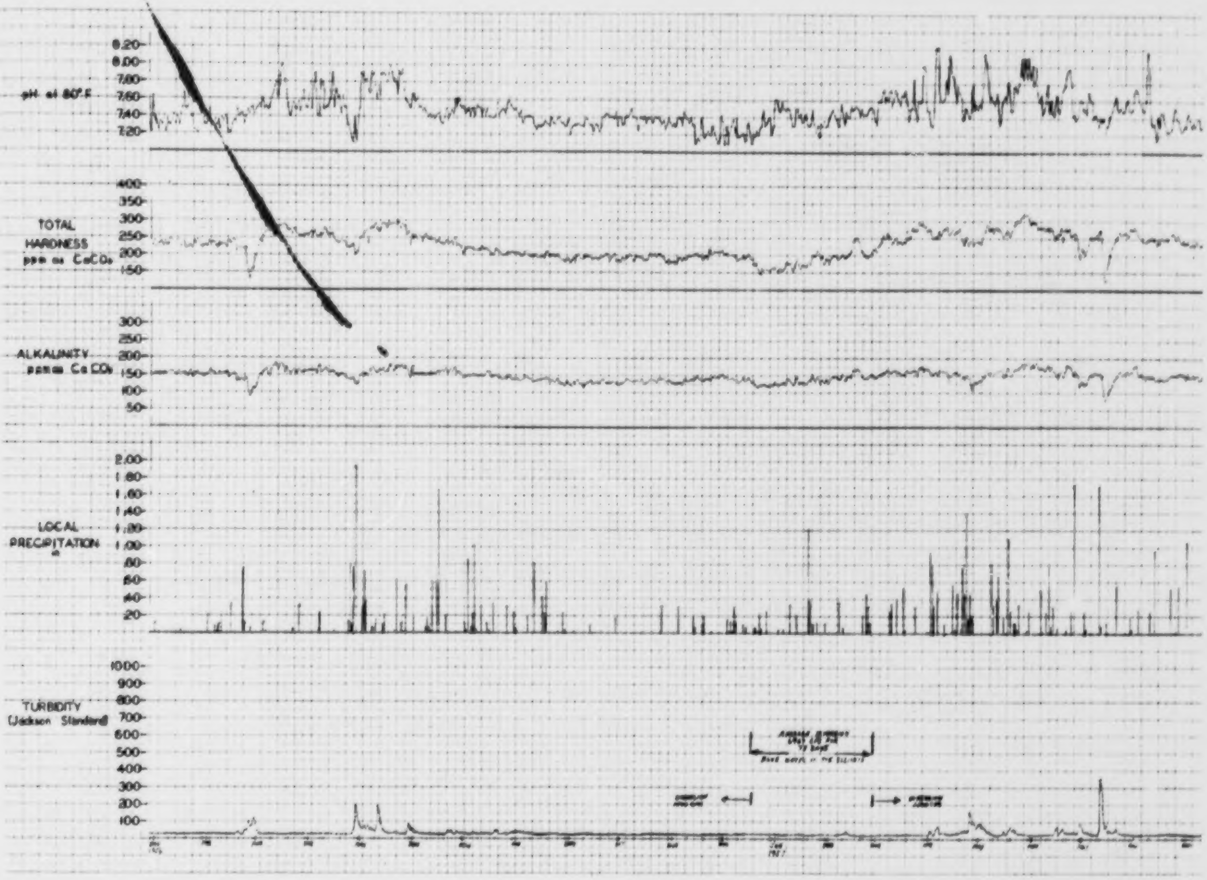

Figure 21. CONTINUOUS RECORD CHART OF WATER QUALITY DATA, ILLINOIS RIVER, 1956-1957.

specifically at industry. Although it is desirable to reduce the pollution rate, drastic pollution legislation at the local level could work to the economic disadvantage of the affected communities. In view of the apparent advantages of the interstate compact system for basin control, intelligent use of the Public Health Service National Water Quality Network may reconcile some of the confusion and inequities relative to pollution.

It has been interesting for the writer to note that, in twenty-five years of personal industrial water-treating experience in various areas, not once has a water problem been traced directly to industrial pollution. The same cannot be said for municipal or agricultural sources. Admittedly, many industrial applications are not concerned with tastes and odors, so this does not mean to imply that industrial pollution is non-existent. It is recognized as a serious problem, but assuredly a problem not restricted to non-voting industry.

It is a sincere personal desire that the Public Health Service National Water Quality Network will ultimately result in the establishment of realistic basic stream water criteria which can, under actual and not by hypothetical control, be upgraded from time to time as industrial and public awareness progresses. The tool has been provided, and only a means of cooperative application is necessary.

In this respect, the following quoted excerpt is from the Report of the President's Materials Policy Commission:

> "It cannot be too strongly emphasized that planning for the United States must mean not rigidity, but intelligent flexibility; not dictatorship and centralization, but cooperative and shared responsibility for the common good."

THE CONSULTING ENGINEER'S NEED FOR WATER-QUALITY DATA

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All aspects of water quality are of interest to the consulting engineer. He is concerned with the "who, what, when, where, and how" information on water quality. In addition, he should do all he can to foster interpretation and publication of water-quality data. Collection of masses of data that are promptly filed and forgotten, or improperly reported, is wasted effort.

A consulting engineer engaged in work on water supply and waste-water disposal encounters a variety of problems ranging from soil mechanics and structures through chemistry and biology. Generally, the time available to the engineer for the solution of the problems associated with a particular project is quite limited. Often the problem is a critical or controversial one. If it were not, probably he wouldn't have a job. In many instances the consultant has to dig out and work with the data available. He usually has to be his own "harvest hand" when it comes to gathering water-quality data and often the "crop" yield is disappointing - particularly where ground waters are involved. Also, he may find "weeds" where he expected to harvest valuable "grain." Separation of water-quality "wheat" from water-quality "chaff" is not the least of his problems.

Important and necessary as they are, the acts of collecting and tabulating water-quality data, alone, will not yield solutions to problems. Interpretation of the data is the next step. This involves a knowledge of what is important to the specific situation and what is not. Engineering always involves "giving" and "taking" but the engineer should have a pretty good idea of how much he is "giving" and how much he is "taking." For this, there are no substitutes for good background knowledge, sound judgment and experience.

Essentially, the consulting engineer's needs for water-quality data do not differ from those of any other investigator concerned with the utilization of water resources. Physical, chemical, and biological data are all of interest to him. Depending upon the problem confronting the engineer, certain aspects of water quality may be much more important than others. For example, in judging the suitability of a proposed well-water supply for a city, the engineer would be much more concerned about data showing a trend toward increased saltiness than, say, about a similar trend toward higher hardness or iron content. The latter constituents can be reduced by treatment, whereas it is generally not feasible to install facilities for the removal of salt from a municipal water supply. Certainly the engineer would want to take a long hard look at the alternatives before embarking on a saline water conversion program for a city supply.

SOURCES OF WATER-QUALITY DATA

Water-quality data may be available from numerous sources. Some of the best sources are the U. S. Public Health Service, U. S. Geological Survey, state health departments, state and interstate water-pollution control agencies, state geological surveys, universities, and drilling contractors. Water-treatment plants and industries, notably power plants, are also excellent sources of data. The "network data" published by the U. S. Public Health Service are worthy of special notice. [1]

COMPLAINTS REGARDING WATER-QUALITY DATA

The principal complaint regarding data on water quality is that there is not enough of it. The problem, as usual, is money. During this symposium, we shall hear a good deal about "harvesting" and processing water-quality data. It would also be interesting to hear a discussion on "How to Finance the Planting, Cultivation, ahd Harvesting of Water-Quality Data." Water-quality data are a matter of concern to everyone, yet relatively few are aware of their great importance. This is only one aspect of the water "problem." Somehow the story must be taken to the people who eventually pay the bill.

Notable data deficiencies are encountered in the field of ground-water resources. The bulk of the smaller cities in this country, and a number of large ones, many industries, and thousands of farmers are dependent on ground water. Despite the obvious importance and value of our ground-water resources, it is surprising how little we know about them from the standpoints of both quantity and quality. Probably some ground-water resources are being over-exploited, while others remain to be discovered, or their potential assessed. Subsurface pollution, an insidious destroyer of ground-water resources, has not received nearly enough attention.

If a consulting engineer is interested in water-quality data, it follows that he must be interested in "quality" data. There is too much sloppy laboratory work done and too many data are worse than useless because of gross inaccuracies. To compound the confusion, good data are sometimes improperly reported, The truth of the matter is that there are times when we, the professionals, do not know what we are talking about. For example, chloride - a constituent of common salt - is universally present in natural waters. Sometimes it is reported as chloride ion (Cl^-); other times, unfortunately, as sodium chloride ($NaCl$). This is not a serious matter as long as the distinction between the two methods of reporting is made absolutely clear. Often it is not. A water that contains no more than 400 parts per million of chloride expressed as sodium chloride ($NaCl$) is fairly satisfactory for municipal use; one that contains 400 parts per million of chloride expressed as chloride ion (Cl^-) is unsatisfactory. It does not take much imagination to foresee the confusion that will arise if several laboratories are involved in reporting chloride results and their reports do not clearly indicate in exactly what terms the chloride data are reported. Other examples of similar confusion could be cited. At this stage a special warning to engineers and others engaged in interpreting results of water analyses seems appropriate. --Read the fine print on the analysis report like you would the fine print in a contract. Sometimes you will be surprised at how the results are reported.

CORRELATIVE DATA

Certain correlative data are important to the engineer studying a water-quality problem. These include hydrologic and water-use data, information on sources of pollution, and geological information.

Of the hydrologic data available, probably the stream-flow records, so carefully collected, analyzed, and published by the U. S. Geological Survey, in cooperation with state agencies, are the most useful. A recent Geological Survey publication on Flow-Duration Curves[2] describes the preparation of a "quality-of-water frequency curve."

The following chloride data for the Smoky Hill River at Enterprise, Kansas, will illustrate the importance of stream-flow data in connection with the interpretation of water-quality information.

Sampling Date	Chloride (Cl^-) Concentration Parts Per Million
November 15, 1956	450
December 17, 1956	925
January 29, 1957	1195
February 20, 1957	885
March 27, 1957	670
April 25, 1957	214
May 20, 1957	14
June 26, 1957	18
July 29, 1957	74
August 26, 1957	113
September 18, 1957	50
October 31, 1957	117
November 29, 1957	279

On the basis of quality data alone it would be difficult to give an intelligent answer to the question: "What is the chloride concentration in the Smoky Hill River at Enterprise, Kansas?" Any inclination to average the chloride data should be firmly resisted. This could be done, but its only value lies in practice in arithmetic. To interpret these results correctly it is necessary to consider stream flow. During the sampling period, flows at the Enterprise gage ranged from about 50 to more than 14,000 cubic feet per second. This variation in flow had a profound effect on water quality. The clear-cut, reciprocal relationship between chloride concentration and flow is shown in Figure 22. This is for illustrative purposes only. Not all available data were used and more refined plotting procedures are possible. No

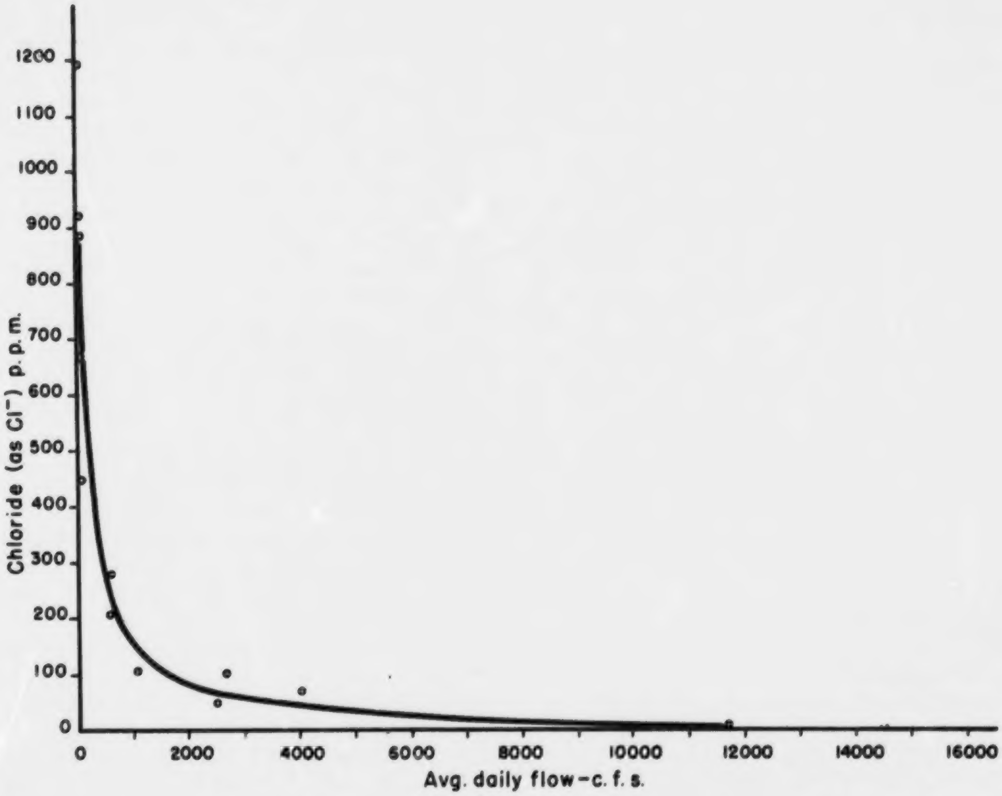

Figure 22. SMOKY HILL RIVER AT ENTERPRISE, KANSAS.
Chloride data from Kansas State Board of Health.
Flow data from U. S. Geological Survey.

attempt was made to analyze, statistically, the relationship between flow and chloride concentration. However, it is virtually certain that statistical analysis would show a high correlation coefficient, indicative of a close reciprocal relationship between chloride concentration and stream discharge. The chloride data were obtained from a Kansas State Board of Health water-quality publication.[3] In the latter, flow data are tabulated along with quality data. This procedure is certainly a sound one and its widespread use is recommended.

A CITY WATER PROBLEM

Experiences, as a state sanitary engineer and a consulting engineer, on many occasions, have focused the author's attention on what he considers a rather inadequately explored area in the water-quality field. The problems of water supply and treatment and water pollution control have been so numerous and pressing that, naturally, we have concentrated a great deal of our study and research effort on them. However, we should always bear in mind that the public pays the bill and that the public judges us, not by our good intentions, but by our performance. The water consumer is equipped, by nature, with extremely sensitive analytical apparatus. With his senses of taste, smell, and sight he routinely monitors the water supply. His monitoring equipment is always plugged-in, warmed up, and resonant to the proper "wave length." The sampling point is the water faucet in his home. Here is where quality is judged -- not at the water treatment plant. It matters little to the consumer that a quality product may be leaving the water treatment plant. It's what is delivered to him that counts, and there are many opportunities for water quality to deteriorate in that vast complex of tanks, buried valves and pipes that we call the "distribution system." A high proportion of the dollars invested in water systems is spent on distribution works; yet, much remains to be learned about distribution systems, particularly with respect to their influence on water quality, and vice versa. Do not misunderstand these remarks. The water works industry has learned much about water-quality problems in the distribution system. In support of this statement it is noted that between 1940 and 1955 the Journal of the American Water Works Association carried 14 articles classified in the "Journal Index"[4] under the specific heading "Quality Maintenance in Distribution Systems." Dozens of others appeared under the classifications "cross connections," "pipeline growths," and "corrosion." Nevertheless, water utility managers, water works engineers and chemists and consulting engineers need to know more about the attenuated chemical and biological reactions that most certainly occur in distribution systems.

It is not easy to visualize the difficulties that may be encountered, and the parameters of the problem are not readily apparent. In an attempt to establish a crude frame of reference, the author submits the following calculated results. For a midwestern city serving a population of 25,000 with an average water use of about 3.0 million gallons daily, the estimated internal area of the water mains is 17 acres, or about 0.7 acre per 1,000 water users. Similar computations for a typical portion of the distribution system of a city having a population of 750,000 gave a value of 4.7 acres per square mile of urban area, corresponding to, roughly, 0.7 acre per 1,000 consumers. Calculations based on statistical data published by the American Water Works Association[5] suggest that a value in the neighborhood of 0.6 to 0.7 acre of pipe surface per 1,000 consumers is reasonably representative. Whether the value is one-half acre, or one acre, is of no great significance. In either case, the area of pipe exposed to water is a substantial one, and there must be great opportunity for slow chemical or biochemical reactions to occur at the pipe-water interface. Many of these reactions may produce adverse effects on water quality. Certainly we have ample evidence that water quality is not, as a rule, improved during distribution. Attention is called to the fact that the area calculations are based on smooth pipe. Corrosion of the interior of the pipe probably would increase the "active" area exposed to the water. Doubtlessly, many other interrelated factors such as time of contact, velocity, turbulence, etc., are also important.

Another calculated result is of interest. Assume finished water is pumped through one mile of 12-inch water transmission main. A conservative hydraulic load for a 12-inch main is one million gallons daily. Assume this main is in service for 10 years, which is perhaps one-tenth, or less, of its life. Assume further, that the pipe continuously carries water at a rate of one million gallons daily and that the water, as it moves along the pipe, through some chemical or biochemical reaction, deposits 0.1 part per million of material on the pipe surface. This might be organic "goo," iron oxide, calcium carbonate, etc. At the end of 10 years, assuming that the deposited material all "sticks," the pipe surface will be coated with about one and one-half tons of whatever was deposited. If the deposit were uniformly distributed over the interior of the mile of pipe, its thickness would be less than 0.1 inch and it might not have much effect on the hydraulic capacity of the pipe. That is another story, albeit an important one. The question here is - what would be the effect on water-quality during the 10-year period, and subsequently? Suppose that after this 10-year period, water-treatment procedures were altered slightly. Would the deposit stick or would it break loose and be discharged in small chunks at the end of the pipe. Suppose that the deposit was organic material and that the chlorine residual at the water treatment plant was changed from a mild residual (chloramine) to a "hot" residual (free chlorine).

Would tastes and odors result from interaction of the organic matter and the "hot" residual? Finally, if any of these things happened, would the customers appreciate them?

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WATER QUALITY DATA AND SUSTAINED FISH HARVESTS

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Any consideration of water quality in relation to public use must be based on a definition of the use and of a demonstrated responsibility for its control. One important use of water is for the production of fish.

Conservation agencies which deal with the preservation and production of fish in public waters must act on the premise that all areas under their jurisdiction are to be utilized primarily for the maximum production of fish and the attainment of the greatest practical annual harvest of fish. To whatever extent local demands for multiple water use require, this position will be modified. In some cases it may be abandoned altogether in favor of another more important water use. Since the problems and philosophy of multiple water use vary extremely in different areas, consideration of them must, for our present purpose, be omitted entirely if meaningful generalities are to be drawn. We will therefore confine these remarks to the problems confronting the fishery biologist and administrator in the production of a full fish harvest.

Of these problems, the need for good water quality data in both fishery research, and water quality control as they apply to fisheries will be considered. At the present time our lack of exact knowledge of fish needs and the effects of the host of relatively new industrial wastes on fish production complicate the task of meaningful water quality measurement and the setting of standards. As will be shown, these requirements are not as well defined as is the case with industrial or drinking water. Although there is still much to be learned before water quality is directly related to the development of full fish harvests, improvements and innovations in instrumentation which is designed to measure and record water quality will greatly speed the task and permit more satisfactory application of our present knowledge to immediate problems.

DEFINITION OF A HARVESTABLE CROP OF FISH

A fish population that will provide a full harvest is one which provides a maximum annual yield of desirable fish for industrial, sport, or food use. This crop must consist of types of fish that are useful to the public who, under conservation laws, are entitled to exploit this part of the public domain. Fish, however abundant, cannot be considered a harvestable crop unless they are of a type which will be taken by those who have access to them. A desirable population of fish is present in a particular water only if it will yield the maximum annual crop possible from undisturbed and unpolluted waters of the area.

There is a common misconception that the mere existence of a fish species complex normal to a particular water is evidence that a harvestable crop exists and that water quality has been adequately maintained. However, without demonstration that a sustained annual yield of fish in terms of pounds per acre per year can be harvested, this assumption is untenable. The position that absence of fish kills or other evidence of acute toxicity in a water demonstrates that the water can produce a harvestable crop is likewise untennable.

The difficulty of determining actual or potential fish yields in terms of annual poundage of production is great and therefore the control of acute toxicity often appears to be the only practical road open to the engineer, or others who attempt to set water quality standards. While this difficulty points up the need for better data on water quality and better means of appraisal of fish yield, it does not invalidate the basic criteria of a harvestable fish population.

WATER QUALITY SUITABLE FOR PRODUCING FISH HARVEST

On the assumption that full fish harvest means maximum annual production of desirable species in terms of the weight of the yield per acre each year, the needs of fish can be broadly outlined. First, suitable water quality exists only when all stages in the life history of the fish can be completed with the minimum mortality and the maximum growth rate consistent with the grographical location and geological nature of the area in which the particular water is situated. Natural mortality, rate of growth, and total potential yield under natural conditions will vary greatly with the location and fertility of the water and with variation in the natural species complex. For this reason no absolute standards can be set for either mortality rate or growth. These factors must be determined under natural conditions in each habitat.

Production of fish depends first on their ability to reach the spawning beds and to complete the spawning act successfully. If quality of the water inhibits the characteristic spawning behavior and movements it is inadequate.

The egg and larval period which follows successful spawning is often the most critical period of the entire life history and is the stage during which the greatest influence on the subsequent crop is exerted. Eggs and larvae are very sensitive to changes in their restricted environment and are unable to escape, even momentarily, from unfavorable conditions. Assessment of mortality during this stage is difficult and determination of causes of observed mortality in the natural habitat is greatly complicated by the lack of instruments and techniques for measuring the factors which exert control over survival.

After fish pass the egg and larval stage, water conditions must permit maximum survival and growth of individuals. Fish which contribute to a harvestable crop must also live in water that is free from materials which will taint the taste so that it is unsuitable for human consumption. Finally water quality must be such that fishfood organisms and the entire food chain leading to the food can be produced fully.

Evidence that all stages of fish life history are being completed in conditions of satisfactory water quality will ultimately be derived from the yield of fish flesh measured in numbers of pounds per acre per year.

In our zeal to produce and maintain waters of high quality for general use it is often assumed that the needs of fish, the needs of industrial water users and the needs for drinking water are more or less parallel and that the solution of any one of these problems will solve the others. While in some cases this may be true, in many instances industrial requirements for water purity will be far more stringent than those needed for maximum fish production and standards for drinking water may impose conditions which are actually less than optimum for maximum fish production. A very simple example is that exhibited by chlorides. Chloride ions when associated with ions non toxic to fish can be tolerated at levels which are completely unacceptable for many industrial uses and for drinking water.

Criteria of water quality based on coliform counts will have little or no significance for fish production. Nitrogen levels which might very well make water unsuitable for public drinking supply if present in certain forms will not have a detrimental effect on fish but may enhance total productivity. In this connection it might be pointed out that some of the most productive fish habitats in the world are made so by the daily introduction of night soil into the water.

Some insecticides are highly toxic to fish in quantities that are almost undetectable by ordinary analytical methods and would be of no consequence to most other uses. In view of these facts it is imperative that the quality standards needed for different water uses be determined independently and applied with specific objectives in view.

THE PROBLEM OF MEASURING WATER QUALITY FOR SUSTAINED FISH PRODUCTION

The most pressing problem of water-quality measurement with reference to fish production is the maintenance of continuous observation over a 24 hour period. Various types of observations can now be made adequately on a continuous basis but others must be made by laborious methods which frequently have inherent defects that make the data unsuitable for estimating the effect on fish production. It is well known that slugs of deleterious material which may enter fish producing waters during very short periods are capable of destroying fish or greatly reducing fish production by elimination of food organisms and early stages of eggs or fish without any overt evidence in the form of acute fish kills.

Low oxygen levels that exist for only a short period of time may have very deleterious effects in an environment which may appear to have ample oxygen throughout the day. Rapid changes of pH within the normal tolerance levels of fish may result in fish mortality, inhibition of growth rate or lowered survival of immature fish stages. Similarly, rapid changes of temperature within the normal range of tolerance may cause mortality or inhibition of growth. Many other materials which affect some stage of fish may exert their influence over short periods. It is therefore, highly desirable that where there is possible pollution all materials which may affect fish in any way be monitored on a 24 hour basis.

The second major problem facing fishery workers is the measurement of water quality in what may be termed the microhabitat. The microhabitat is the immediate environment which surrounds a fish, or fish egg, or fish food organism. It may vary extremely from the general conditions of the habitat as a whole, and will determine the actual fate of the organism. A crude analogy to our aquatic problem might be the case of the deer hunter who creates a microhabitat that permits his overnight survival by crawling into a sleeping bag when temperatures a few inches away are low enough to cause him to freeze. Standard weather instruments in a standard Weather Bureau shelter would be difficult to pull into the bag to give documentary evidence of why he didn't freeze to death.

An example of a microhabitat important to fish is the zone of soil-water interface where eggs may be deposited and where fish larvae reside for several days after hatching. It has been demonstrated by some of our current studies on northern pike and black bass that conditions of oxygen, CO_2, and decomposition products at this point are considerably different than in water a few inches above the bottom or in main channel and main lake areas. Without ability to measure variables in this microhabitat we are unable to relate observed mortality or survival to water quality conditions as they exist in the main body of water.

A second example of aquatic microhabitat is the restricted area where fish food organisms are produced in weed beds, or extremely shallow marginal water. A third example is presented by the escape areas for fish which are distinct from main bodies of water. These escape areas may be strata of cold water eminating from the springs along the bank or seepages of suitable water in limited locations within areas which are otherwise unsuitable for fish.

Microhabitats, whether favorable or unfavorable, may be created by stratification of temperature, deleterious materials, or fresh water where a gradient between favorable and unfavorable conditions exists. Without suitable instruments to measure these microhabitats the fishery biologist working on problems of water quality is unable to determine definitely what the gross observations in main channels mean with reference to actual conditions existing in areas that determine production of a harvestable crop.

In emphasizing the importance of the microhabitat it should be pointed out that the fishery biologist cannot make a general and all-inclusive blueprint of microhabitats which should be measured. The microhabitats in each type of macrohabitat and perhaps for each species will have to be determined before adequate measurement can be attempted. The contrast between microhabitats for yellow perch eggs and black bass eggs is a case in point. The perch eggs are usually festooned over vegetation or under-water objects that keep them from direct contact with the bottom. Bass eggs are in direct contact with the bottom at the soil-water interface. Conditions at these locations even in the same water are different and both may be quite different from the main body of open water.

A third major problem which confronts the fishery biologist in his appraisal of water quality problems and fish production is the recording and processing of large quantities of data. Water quality data especially that collected from automatic instruments must be recorded in such a way that it can be stored easily, transferred to tapes or cards for automatic processing and be easily retrievable on demand from the filing system. When the proper degree of automatic instrumentation becomes available, this necessity will be acute. In many of our own studies conducted during recent years where such simple types of data as continuous temperature and light records and periodic observations of pH have been made these problems have been large and extremely time consuming. For the much larger quantities of data which will be collected to guarantee the protection of fish producing areas in large water systems the data will become unmanageable and in effect useless for many purposes without the capability of automatic processing.

TYPE OF DATA NEEDED

The type of data needed on water quality will be summarized briefly since at the present time any attempt to give a complete coverage would be difficult if not impossible. Since fish are cold blooded organisms whose metabolism is greatly affected by changes in temperature and because temperature determines the effects of many materials on fish, it is important that temperatures be accurately and continuously recorded and that suitable equipment is available for simultaneous observation at numerous points over relatively large areas or at a series of depths. In some situations continuous observation throughout the 12 month period is highly desirable.

A continuous record of dissolved oxygen levels are likewise highly desirable since this may be the most critical factor determining the well being of fish and one which, like temperature, may determine the effects of other materials. Records in the microhabitats are especially important.

Continuous records of pH are also important if there is a likelihood that rapid changes will occur even within the normal tolerance ranges of fish or there is a probability that slugs of extreme alkalinity or acidity may occur.

Potentially lethal or detrimental materials which may be accumulated either as precipitates or which may be accumulated in the body of the fish must be evaluated. Specific materials which are toxic and which originate from some particular industry should be observed. In many types of research studies continuous observation of nitrogen and phosphorous in the water would be very desirable.

Measurement of silt load and light transmission are also necessary for a complete evaluation of fishery problems. Capability of water to transmit light will determine the effectiveness of primary production based on the growth of microscopic plants. Silt load while it will usually have a small effect on larger fish may have a controlling effect on fish eggs or larvae. It has been shown that the removal of fine silt from fish hatchery water will increase the survival of eggs significantly. It is also necessary to have an adequate measurement of the radionuclides which may be entering the water or which may be accumulating in bottom materials.

Attempts to pinpoint needs for water quality data more specifically must wait on accumulation of greater knowledge of actual fish needs that now exist.

GENERAL AREAS WHERE NEEDS FOR WATER QUALITY DATA EXIST

There are two general areas of study in which we need better water quality data to assist in the production of high sustained yields of fish. They are research and water quality control. As has already been pointed out, there are many needs of fish and many reactions of fish to known chemicals and conditions which we do not at present understand. In order to cope with the problem of maintaining adequate water quality where an ever-increasing variety of materials are being added to water a large amount of research must be done. This research is required to determine the effect of these materials on fish populations and to distinguish the difference between natural causes of mortality and inhibitions of growth and those brought about by the materials introduced to waters from industry or municipalities.

The biggest needs in research are related to the determination of factors controlling success of hatch and survival of fry, and also the factors controlling the dynamics of the food chain and ultimate production of fish food. Likewise, factors affecting rate of growth have been imperfectly explored with reference to water quality. It is known that certain materials will inhibit growth rate. Some of these materials are produced by fish themselves under crowded conditions and may be related to common pollutants which are not now recognized as detrimental. Research on many of these problems is hampered by lack of adequate instrumentation to measure water quality in various portions of the natural habitat. The most acute deficiencies are adequate instruments to measure oxygen, pH, decomposition products, and materials which stratify or settle out in the microhabitat where the first and most vital stages of fish survival and food production occur.

Equipment suitable for such research observations may be elaborate and relatively costly and require expert supervision to keep it in operation. While this is not desirable it is tolerable in a research project.

The second and perhaps more urgent field where better measurement in connection with fisheries is needed is in quality control of waters. Before discussing the specific needs for instrumentation in quality control an important problem facing biologists should be emphasized. The effect of many deleterious materials and some which are not in themselves harmful may be greatly altered by synergistic or antagonostic reaction in the presence of other materials. Since these reactions are, for the most part, unpredictable at the present stage of our knowledge, precise measurement of the particular chemicals or ions may not be of much value to us in assessing their effect on fish life. As a result of this situation the only truly valid appraisal of the effect of a potential toxicant or group of toxicants will be bioassay with fish or invertebrates in the water which receives the deleterious material. Where bioassay shows that conditions for fish are unsatisfactory in the presence of several known toxicants it is often extremely difficult to determine which toxicant is responsible or whether several materials working in the presence of naturally occurring constituents of the water produce the observed effect. Accurate monitoring of all suspected materials may be the only way by which the results of bioassay can be directly related to the source of pollution and adequate water quality maintained. There are some apparent exceptions to this generalization but even these cannot be considered as independent.

Instrumentation needed to maintain water quality levels which are suitable for the production of a harvestable crop of fish should be rugged and capable of sustained operation without constant supervision by highly trained people. It should be so constructed that it can be operated by remote control and the records telemetered to a central point. It must be sensitive enough to record conditions which exist only for short periods of time so that rapidity of change can be detected. No device which employs principals of summation or means of series over an extended period will be satisfactory for determination of most materials of importance in fish production. Materials which are present at sublethal levels but whose effects are cumulative such as radionuclides, chlorinated hydrocarbons, and the like may be adequately measured by a process of summation. Materials the effects of which relate largely to fertility of the environment and which are of particular interest in research studies of productivity may be summed over short periods of time rather than continuously recorded. As our knowledge of fish in relation to various pollutants increases and the distinction between fish production and fish survival is clearly understood by biologists, sanitarians and engineers more precise specification for instrumentation can be presented.

SUMMARY

To summarize the problems of measurement of water quality in relation to production of a crop of fish we should point out:

(1) a harvestable fish population is one that provides continued annual yields of desirable fish.

(2) water suitable to produce a sustained harvestable crop must permit successful completion of all stages in the life history of fish and fish-food organisms.

(3) water suitable for fish is not necessarily suitable for other purposes and water designed for other uses may not be suitable for fish.

(4) instrumentation suitable for determining water quality in connection with fishery problems must record on a 24 hour basis and in a non-cumulative fashion.

(5) instruments must be developed to measure conditions in the microhabitat. At present inability to make these measurements successfully is one of the biggest deterents to detailed research on many problems.

(6) instrument data must be collected in a form which can be stored and analyzed by machine.

(7) instrumentation must be so devised that it can be controlled from a remote location and the results telemetered to a central point. While the requirements outlined above may not at present be feasible economically and in some cases may require extensive technological development, realistic attacks on the problem of making water quality suitable for sustained production of fish must work toward the accumulation of data in the manner outlined herein.

NEED AND UTILIZATION OF WATER QUALITY DATA BY FEDERAL AGENCIES

K. S. KRAUSE
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Public Health Service
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I am sure that the need for basic data pertaining to scientific subjects is old as civilization itself, and in all probability, will continue to be in short stock as long as mankind is still inquisitive enough to want to know more about the Earth, and the Universe in which he resides.

The amount of basic data to enable us to plan and develop water resources in an efficient and coherent manner has increased over the years, not in a linear fashion, but rather in a geometric progression. This geometric increase has come not only in a quantitative sense but also in the various types of information required. For example, when the Nation began to develop its water resources, it was navigation needs that were paramount. Then came needs for power - water power; then flood control, water supply, irrigation; each requiring more sophisticated and detailed data about the dynamic and elusive phenomena of nature described as a river, lake, stream or estuary. While it took 150 years to reach the point of water resources development we now enjoy, most of the progress has come in the last 35 years, and during this same 35-year period, basic information requirements have likewise pyramided. The need for basic data is demonstrated by estimate of funds to be spent during the years 1961-1975 inclusive, prepared by the Bureau of the Budget. These estimates indicate that seventy seven and one-half million dollars will be spent for obtaining and processing basic water quality data during that period. I personally feel this is a very conservative estimate.

The title of this paper indicates that discussions will be limited to water quality basic data needs of Federal agencies. I plan to take a few liberties with this title, particularly since it is difficult to distinctly separate water quality from water quantity.

First, let us consider the Federal agencies having legal responsibilities for collection of all kinds of basic data information needed to plan, develop, operate and maintain water resources projects. The old National Resources Board listed 15 in 1940; the Task Force on Water Resources, Second Hoover Commission, listed 24 in 1955. These, of course, collect all kinds of information on water resources.

If one asks, "How many Federal agencies have an interest in water basic data information?" the listing reads like an organization table of the Federal Government. In reviewing the several reports in which such compilations have been listed, we estimate that there are 48 Federal agencies which have utilized or may utilize basic water quality and associated hydrology in some manner. The purposes for which these agencies utilize water quality data may be grouped roughly as follows for:

1. Planning and development of water resources projects.

2. Utilization of water resources.

3. Testing against legal requirements.

4. Quality control.

5. Measurement of progress in water quality improvement.

The role of water quality in water resources planning is being recognized as complementary to quantity today. Conservation no longer means merely the control and efficient use of water in the quantitative sense. Agriculture, industry, our cities and towns, recreation facilities and wildlife are dependent on water of satisfactory quality, as well as adequate quantity if they are to develop during the years to come. These same uses have a profound influence on the water they use -

most of it adverse, and steps must be taken to reclaim or protect the water, eliminating adverse effects on the next user. The need to foresee and plan the efficient development of water resources, and control the quality of these resources, is now upon us. This development and control promises to be a tremendous consumer of basic water quality data. The Corps of Engineers, the Bureau of Reclamation, and the Soil Conservation Service, as the principal water resource construction agencies of Federal government, are wanting to know how much storage should be included for water supply, and dilution water for natural and man-made pollution control in our inland fresh waters. They want to know what the effects of the quality of water in the system will be on agriculture, potable water supplies, industrial water supplies, fisheries, recreation, wildlife, and navigation. The Public Health Service, under the Federal Water Pollution Control Act, is initiating a program of comprehensive planning, in cooperation with State and interstate agencies, to control and prevent water pollution. This program will make available to the development agencies some of the answers to the questions being posed. Public Health Service and cooperating agency needs for basic information to accomplish this task will be great. To become more specific, the kinds of information we will need, for example, will include:

1. Biological, bacteriological, radiological, chemical (synthetics, organics, dissolved oxygen, inorganics, toxic, etc.) and physical quality in as broad a spectra as possible at selected point of flow and/or quality change.

2. Intense and prolonged information on certain quality parameters from which statistical interpretations, confidence limits, and trends may be established at the same points.

3. Continuous measurements by automatic instrumentation of parameters now in use.

4. Water use data - the volume taken out and returned to the stream at each point of use.

In addition we will need a great deal of information on the demography of region in terms of people, agriculture, industry, and resources to supplement the basic water data. These data will assist us to set up mathematical models mentioned this morning of the river or lake basin into which flow and quality variables, combinations, and behavior patterns may be inserted and the dynamics of waterway closely estimated. This knowledge, plus a program of controlling pollutants at their source to the maximum extent possible will help give us an effective water quality control. Such a plan, together with its costs and benefits will greatly aid us toward a sound and comprehensive water resource development.

Basic water quality information will assist in the utilization phase of the water resources in two ways: It will indicate to the prospective user (agriculture, industry, municipality, recreation) the kind of water which he can reasonably expect to have, and it will indicate to him where and how he must dispose of his waste water in order to minimize pollution and the effects of his waste on downstream users. We can no longer afford a "dog eat dog" philosophy relating to pollution control, but rather it must become a "live and let live" doctrine.

The third general group of consumers of water quality basic information are the regulatory agencies and the potential polluters who are guided by certain legal requirements, standards, or ranges of purity. Here the basic data serves as a measuring device, which is a very substantial portion of the total need. The Public Health Service, through its interstate pollution abatement enforcement activities, is a very great consumer of such information. Other Federal agencies who may be contributors of pollution are likewise interested in such information. It serves as an indicator of the health of the receiving stream or lake. It also indicates the trends and changes occurring, and the corrective actions that contributors must take.

The fourth grouping of uses is one which might be termed quality control. This is an area which is just beginning to be seriously considered, but is certain to have a tremendous future and offers an intriguing challenge to planners, developers, and operators. While quality control is by no means limited to Federal agencies, they will undoubtedly play a significant role in the application of basic data to quality control. While this topic cannot be adequately covered in a few brief sentences, I would like to indicate briefly to you the potential of this concept.

The objective of quality control is to provide within predetermined limits, a given quality of water. This is important because industry, agriculture, and domestic water treatment costs and operating problems are largely associated with fluctuations in water quality.

Quality control can be exercised to some degree wherever a stream flow is regulated, but certainly becomes most effective when pollutants are highly controlled at their source and the flow of a stream is highly regimented, and the two are harnessed together. Theoretically, by measurement of the amount and pollution characteristic of the incoming wastes, the concentration of pollutant at the points of use can be controlled by flow regulation. The degree to which exact quality control can become a practical reality is, of course, dependent on our ability to obtain and correctly interpret the quality information as it relates to hydrology and pollution control and to build and operate the necessary treatment and regulating structures. It cannot be expected that the attainment of these goals will occur overnight; however, one of the most important steps in the achievement of this control system is under consideration here now, that of developing instrumentation which will provide continuous and reliable information on background water quality in several indicator parameters. The correlation of these parameters with stream hydrology and hydraulics will enable us to set the stage for a sophisticated system of quality control which will stretch out the use of water resources in both time and amount, and thus, in effect, increase cur available water supplies. The stream monitoring systems now in use in the lower Mississippi River and in the Ohio River and Delaware are in effect forerunners of this instrumentation concept. The Corps of Engineers has the fundamental flow system already worked out for the Columbia River and the Missouri River. Tied in with weather forecasting and past hydrologic records, the flow system is in effect a statistical problem which a computer supply answers. The results are maximum power generation, irrigation, flood control, and navigation usage of the stream. In addition to a system for computing hydraulic control of the stream, we need now to super-impose the quality picture. This, of course, will greatly increase the complicity of the problem, but it does not render the solution impossible. There is a real need for the realization of such a system, and I challenge all who are here today to apply their energies to obtaining it. Quality, unlike quantity, does not stay within limits set by nature. Water left without quality control measures will become increasingly degraded at an alarmingly faster rate. Therefore, constantly increasing vigilance must be established to keep degradation from getting out of hand.

The last grouping of users are those responsible for providing the Nation with an appraisal of the trends in water quality. This appraisal is a very great responsibility, since the very health of the Nation - both physical and economic - is at stake. The Nation's health rests on our ability to adequately measure the pulse, respiration, metabolism, and blood pressure of the great hydraulic system of this country and translate it into terminology which will give the public adequate information on the quality of our streams and lakes. In my opinion, our efforts thus far have been less than adequate. We are relying to a large extent on indirect and often inadequate methods of measuring the trends and progress in water quality improvement or degradation. Our methods of measurement must be increased in number and even improved in sensitivity and kind if an adequate data gathering and reporting system is to be obtained and maintained. I do not think we have a very great question of duplication of effort among the several agencies gathering such information, but we do have a question of how to multiply these efforts to obtain an adequate picture of water resource quality.

In conclusion, therefore, let me state that we now have means of handling and summarizing data - automatic instrumentation for gathering necessary data on water quality parameters is one of the most important keys to our understanding the dynamics of a stream quality. With adequate understanding, I am certain we can accomplish a great deal in water quality control.

DISCUSSION

MR. B. L. ABELL (Dartmouth College, Hanover, N. H.): Mr. Banks, you as well as Dr. McKee have discussed the case method and expressed confidence in comprehensive planning. Is there a little difficulty involved, and if so, can you discuss how these difficulties are ironed out?

MR. HARVEY O. BANKS (Director, California State Department of Water Resources, Sacramento, California): Pollution control in California has been to the present time, conducted on a case by case study. I think we have gotten to the point now where we have to look a little beyond that. We need to develop long range plans, and then fit individual waste disposal and the other quality problems into that long range plan on a case by case study. I think Dr. McKee would agree generally with that.

MR. RONALD EVANS (Water and Sanitation Market Sales Manager, Minneapolis-Honeywell, Philadelphia, Pa.): Mr. Banks have you ever pursued anything on an automatic basis of data sampling?

MR. BANKS: My department is not a basic reaearch agency. We are looking very eagerly, shall we say, to the development of automatic sampling equipment and as soon as it becomes available and reasonably reliable, we will use that.

CHAIRMAN LOVE: I might say in the Geological Survey we are very much interested in having commercial firms get into this field because they would be likely to make a specialty out of it and thus probably do better than those of us who must attack the problem on a gadgeteering basis.

MR. DON PFITZER (U. S. Fish and Wildlife Service, Atlanta, Georgia): I have a question for Mr. Krause on some of the implications of the models which would be used to analyze our water quality or to monitor water quality and which would help us to give predictions on conditions that will exist.

Two elements that are quite important, I think, to all water quality -- oxygen and temperature -- present a problem in this scale model condition where stratification exists. Is there a way that stratification in reservoirs can be put into scale models and give us the kind of answer that we need?

MR. KEITH S. KRAUSE, (Chief, Technical Services Branch, Division of Water Supply & Pollution Control, Public Health Service, Washington, D. C.): I think you are not the only one that is bothered by questions of this kind. I frankly cannot provide you with an answer to the question which you have raised. This has a bearing on this morning's topic concerning the relationship to the use of the stream having a system of multiple dams and the effect on the oxygen in the stream and of course its utilization for fisheries. This certainly is one of those areas which we must explore.

INSTRUMENTATION

Chairman, Part I: **RAYMOND J. FAUST**
Secretary, American Water Works Association

Chairman, Part II: **RICHARD S. GREEN**
Chief, Basic Data Branch
Division of Water Supply and Pollution Control
Public Health Service

INTRODUCING THE ORSANCO ROBOT MONITOR

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Ohio River Valley Water Sanitation Commission
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Several years ago in an annual report, the Ohio River Valley Water Sanitation Commission stated it was imagineering a robot monitor to improve its system of river surveillance. This symposium provides an occasion to announce that this aspiration is on the eve of realization. Components of the system are completed. And there is reason to believe that rivers in the Ohio Valley will be the first in the world to be under continuous, automatic surveillance for quality control.

Before launching into details, however, two words deserve explanation. Imagineering may be defined as the process of combining ideas to devise something new. And robot is another coined word to describe an automatic device. In brief, the ORSANCO ROBOT MONITOR represents a unique combination of electronic circuitry and instrumentation to perform a series of unattended prescribed operations.

AIMS AND SCOPE OF PROJECT

Components of the ORSANCO robot system have been under development and test for some three years. But the river monitor and surveillance program of which it forms part had its beginnings in 1951. At that time ORSANCO pioneered the concept in pollution-control practice of establishing observation stations for systematic checking of quality and reporting of unusual conditions.

The present network of 43 manually-operated stations has played an important role in securing more effective pollution control. But it left something to be desired. Water sampling and analysis are time-consuming procedures; and it was not practical, of course, to maintain patrol on a 24-hour around-the-clock basis. These and other considerations stimulated exploration of developing automatic devices to maintain constant vigilance on river quality.

This exploration program was formally organized with these objectives:

> Determine the availability and applicability of analytical instruments that might be adapted to river monitoring;
>
> Conduct operating tests and undertake the design of equipment whose functional and structural features would incorporate the reliability and ruggedness required in unattended locations;
>
> Evaluate the application of telemetering devices and methods for data-logging.

From the more than 50 instrument companies who were contacted during initial inquiries, only three were optimistic in terms of supplying instruments that might be suitable for automatic river-quality determinations. This was disappointing. But in retrospect it is not surprising. It meant simply that our needs and desires -- to use a phrase from one manufacturer -- were "somewhat ahead of the art of instrumentation".

In brief, our inquiry revealed that automatic instruments on the market were designed primarily for application to industrial product quality or process control. Many of them could perform continuous analyses; but they did require periodic daily checking and adjustment. Further, the instruments operated best with liquid or gas streams whose composition remained fairly uniform. In contrast, the medium with which we were working -- river water -- is subject to variations in composition and, in addition, carries suspended material. To add more complications, we were seeking instruments that would operate with precision and without checking for at least a week and hopefully for as long as a month.

It was evident also from the responses that our inquiry suggested an unrecognized potential market for instrumentation. The concept of an automatic river-monitoring system was a new one to virtually all of the manufacturers. We have reason to believe that considerable interest has now been stimulated in this endeavor.

EXPERIENCES AND DECISIONS

Several promising possibilities in instruments ultimately were uncovered and placed under test. This work was facilitated through a happy arrangement with the City of Cincinnati Water Works. It was possible to locate our specially-designed trailer laboratory adjacent to the municipal water-pumping station, where a direct tap could be made to the Ohio River intake. This situation was ideal for our purposes. It not only assured a continuous source of raw river water, but the water itself is routinely analyzed by city chemists every few hours and thus data was available for comparison with results from the automatic analyzers.

At the risk of over-simplification, the instruments that received our attention might be classified in two categories: One group is based on the application of photometers. The other type employs electrodes or transducers.

Instruments in the photometric group operate on principles involving measurement of the intensity of light transmission. Many types are available, varying from relatively simple color-measuring devices to the more complex spectro-photometers. These instruments perform either a direct measure of the concentration of a substance in a solution, or do so indirectly by measuring the effect of a chemical reaction resulting from the addition of a reagent.

Instruments of the electrode or transducer type are those which employ sensing devices that present their information-output in the form of a varying electrical impedance or a generated voltage signal. The electrode system may consist of nothing more than a pair of metallic plates, or it may involve the use of permeable membranes and cells containing diffusion liquids. The transducers are simple impedance elements designed to vary in a known manner with the quality characteristics being observed, or they may incorporate more elaborate potential-generating electrolytic cells or pulse-producing ionization chambers.

The ORSANCO ROBOT MONITOR has been designed to use electrode and transducer-type instruments. One factor leading to this decision was the probability of monitors being located in areas where the replenishment of reagents would not be convenient. This problem does not exist, of course, where a monitor is to be used in or near a laboratory.

From the array of instruments that are being tested and placed through various stages of modification, seven have been chosen thus far for incorporation in the prototype ORSANCO ROBOT MONITOR. These provide for the measurement of: Hydrogen-ion concentration, chloride ion, specific conductance, dissolved oxygen, oxidation-reduction potential, temperature and solor radiation. All of these instruments have been modified so that they fit into a standard-size, drawer-type compartment, which we call a module (Figure 23). Thus, the robot monitor can be descriptively termed a "modular multiple-analyzer".

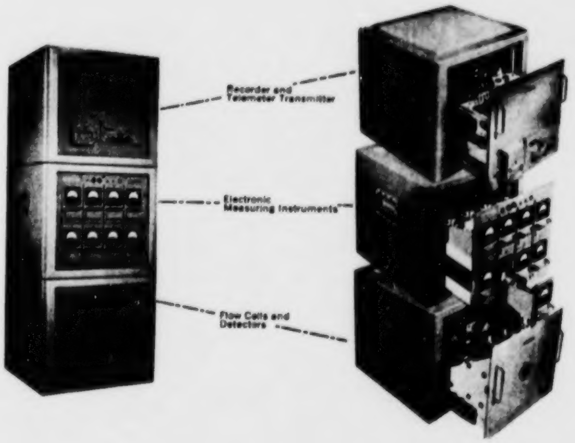
Recorder and Telemeter Transmitter
Electronic Measuring Instruments
Flow Cells and Detectors

Figure 23. THE ORSANCO ROBOT MONITOR

INSTRUMENT DESIGN AND CIRCUITRY

Details of the instruments are described by Mr. Carl Schneider, who serves as ORSANCO's electronics consultant and who also built the equipment, in this fashion:

"Three of the river-quality characteristics monitored by the prototype robot -- namely, pH, oxidation-reduction potential (ORP) and chloride-ion -- involve the use of electrode systems which form electrolytic cells. For pH measurement a glass electrode and a reference electrode are used; for ORP determination a platinum inlay electrode is employed with a reference electrode; and for chloride-ion measurement a silver-silver chloride pressed-billet type electrode and a reference electrode are used. The pH and chloride-ion measurements require the use of an auxiliary thermo-compensator to automatically correct for temperature changes. All reference electrodes are palladium annulus reservoir-type electrodes having adequate solution capacity for long-term, unattended operation.

"Each of these three measurements presents the common problem of measuring a fairly substantial DC potential from a source that cannot tolerate loading to a current of greater than approximately 10^{-11} amperes. In the robot monitor these three analyzers are designed with similar circuitry. Each consists of a unique, stabilized-electrometer input followed by a chopper-stabilized direct-coupled amplifier in an operational-type circuit. The panel meters measure the outputs to the telemeter (0 to 50 mv. DC), but calibrated in the desired engineering units. Temperature compensation, as well as characteristic compensation, are introduced in the amplifier feedback circuit as required.

"Two other parameters being monitored, namely, temperature and specific conductance, involve the accurate measurement of impedance. For temperature measurement a nickel resistance element enclosed in a stainless-steel bulb is used, and for conductivity an electrode consisting of a pair of platinum plates is immersed in the river water. Each sensor is connected as a variable impedance in one leg of a bridge circuit. The bridge supply is DC for the temperature measurement and AC for the conductivity determination. The bridge unbalance created by variation of resistance of the sensor provides the input to an amplifier of the type described previously, but with the electrometer omitted. Compensation for non-linearity of the temperature-resistance characteristic and temperature compensation for the conductivity cell are introduced in a unique manner in the input and feedback circuits. The operational-type circuit lends itself well to this function.

"The monitoring of dissolved oxygen presents the problem of measuring a small current through a Carritt-Kanwisher electrode. This electrode system includes a silver-silver oxide reference electrode and a platinum indicator electrode, both of which are immersed in a 0.5N potassium hydroxide internal electrolyte. A polyethylene membrane covers the electrode system and contains the electrolyte. When this assembly is immersed in water, dissolved molecular oxygen permeates the membrane. Current flow between electrodes, when a low DC potential difference exists between them, is a function of the amount of oxygen dissolved in the water. The analyzer for this measurement uses circuitry similar to that used for temperature and conductivity measurement. Necessary temperature compensation is introduced in the amplifier feedback loop.

"For determination of solar-radiation index, solar cells are exposed on an exterior flat surface. A differential signal is processed through circuitry similar to that used for dissolved oxygen measurement with temperature compensation introduced as required.

"In each analyzer unit the electronic circuitry provides three main functions; (1) it converts the signal from the form existing at the sensing element to the uniform 0 to 50 mv. DC required by the telemeter-transmitter providing offset and range control; (2) it introduces compensation for non-linearity of characteristics and for the effects of variation of parameters other than the one being observed; and (3) it provides its own means for calibration and adjustment in the form of an accurate panel meter and built-in standard "signals" that can be used to check zero and full-scale indications."

This concludes the description as outlined by Mr. Schneider.

STRUCTURAL AND FUNCTIONAL-DESIGN FEATURES

From a structural and functional-design standpoint the following features of the ORSANCO ROBOT MONITOR are also noteworthy.

1. The unit is housed in a weatherproof, stainless-steel cabinet slightly smaller than a standard 66-in. rack panel cabinet, and it consists of three separate identical cubicles. These cubicles (which are 24 inches wide, 21 inches high and 21 inches deep) are designed with nesting tops and bottoms and thus permits stacking them without the necessity for bolting. They are fitted with recessed folding handles on the sides and individually are readily portable.

2. The three cubicles contains, respectively: (a) the flow cells and auxiliary items, (b) the analyzers and power supplies, and (c) the telemeter transmitter. The latter cubicle can accept interchangeably, and without alteration of any connections, a multi-point strip-chart recorder. This is convenient for initial set-up and test prior to putting the monitor into the telemeter network. But more important, it also permits operation of the unit as an independent monitor with recording at the site.

3. The two cubicles containing electronic equipment are completely sealed when all plug-in circuits are in place. They are provided with thermostat-controlled heaters to maintain a constant temperature of 125 deg. F. to aid in maintaining stability of the electronic circuitry. All electrical connections between cubicles are made by means of AN-type and coaxial connectors to facilitate assembly and disassembly. The system operates with power supplied from a 115-volt, 60 cycle source.

4. The flow-cell cubicle, which is placed on the bottom in the assembly, provides mounting space in a sliding drawer to accommodate as many as eight flow cells in addition to a stainless-steel constant-level water tank. The flow cells are machined from solid blocks of Lucite. Analyzer electrodes are inserted in these cells through holes in snug-fitting rubber stoppers, which are clamped in place to act as a seal. The pull-out drawer facilitates the inspection and cleaning of cells and electrodes.

5. An automatic sample-taker is also incorporated in the flow-cell cubicle. This permits the storing of a quantity of river water when an abnormality of quality occurs that might warrant more detailed laboratory examination. The sampler mechanism is triggered by a high-limit or low-limit control on any selected analyzer. This control energizes a solenoid-operated valve on the constant-level tank to initiate the draining of a two-gallon sample into a plastic bottle. Automatic samplers may be used with any analyzer as desired.

6. All analyzer units are identical in form regardless of function. Designed as plug-in modules, they are 4 inches by 7-1/4 inches by 12 inches deep. The modules are placed in two rows of four across the front of the analyzer cubicle. They share common power supplies, which are mounted behind them in the cubicle. The panel rack assembly for the eight modules slides forward to give access to the power supplies. Individual analyzers are equipped with similar circuitry to as great an extent as possible, and the major printed-circuit sections are interchangeable between the different types of analyzers. Although the electronic circuits are designed for long-term stability, periodic calibration checks and adjustments will be made on a regular schedule (initially every 10 to 14 days) when the electrodes and flow cells are cleaned. Built-in standard circuits have been included so that the serviceman need only press the button of a momentary-contact switch, read the panel meter, and make a simple front-panel screwdriver adjustment of the zero, if required; by flipping a toggle switch he repeats the procedure for full-scale calibration. Thus the serviceman need carry no meters or tools other than a screwdriver. Front-panel meters are calibrated to one per cent accuracy and are intended to be used as the calibration standards. Should an analyzer develop some circuit fault not immediately apparent, it is simply pulled out and replaced by a similar plug-in unit -- this change-over can be done in a minute. The faulty unit is then returned to headquarters for servicing.

These and other features were incorporated in the prototype robot constructed for ORSANCO by the Engineering Specialties Company of Madeira, Ohio. This company, which engages in development of custom-built electronics equipment, is also retained by ORSANCO as consultant on the telemetering and data-logging units of the river monitor system.

TELEMETRY AND DATA LOGGING

For the transmission of information from the river monitors to the control center in Cincinnati, the Minneapolis-Honeywell Company designed and built for ORSANCO a low-frequency multiplex system. It includes a telemeter receiver and an associated strip-chart for the control station, as well as a transmitting unit to be used with the analyzers at each river station.

The telemetry has been devised to interrogate up to 40 monitor stations and to record 10 variables from each station. Signals are transmitted over a Grade I intercity telegraph line. This is the least expensive of the wire services available for leasing. In order to take advantage of this low-cost service the ORSANCO system was designed with suitable electrical characteristics. It is designated as a system for operation in "1/2 duplex time-multiplex mode on a single loop in the 0-15 cycle per second frequency range". The cost of the service averages 75 cents per mile per month, plus a "drop charge" for each robot monitor station in the system.

At time intervals, which can be predetermined, the Cincinnati control center will automatically interrogate each monitor station calling them in numerical sequence. Each monitor responds to its coded call and transmits signals in orderly sequence that provide data for recording the quality characteristics being measured.

All of this information is, in turn, fed into a data-logger; the encoder of the logger is driven by the telemeter strip-chart recorder. The data-logging portion of the equipment was designed by the Datex Corporation of Monrovia, Calif. to be compatible with the telemetering system. Purpose of the data-logger is to transcribe telemetered signals from the monitors on a permanent, tabular form and also make a punched-tape record. The latter will permit handling the data in a computer for determination of maximum and minimum values, rate of occurrence, and other routine evaluations.

The data-logger uses the recorder-driven encoder, with suitable control circuitry and programming. It is supplemented with an item counter and digital clock, to provide a complete series of information to an IBM typewriter and a Friden tape punch.

The resulting tabulation of data has been planned to provide an overall presentation of river conditions available for prompt interpretation, and which will be continuously maintained up-to-date. Information from each station is tabulated on a single horizontal line arranged in vertical columns for each parameter being measured. Thus the interrogation of all remote stations in sequence will provide in each column a summary of quality variations throughout the length of the river.

By integrating various components with elements of the telemeter receiver during the initial design stage it was possible to achieve a 70 percent savings in cost over the original estimates for the data-logger.

SOME PHILOSOPHIC ASPECTS

From this description and the illustration accompanying it you will have gained an impression of the function, design and appearance of the ORSANCO ROBOT MONITOR. However, this presentation takes care of only part of the obligation placed upon the author when he accepted the invitation to address you. He was asked also to "deal with some of the philosophical considerations" relating to the ORSANCO surveillance program.

For this purpose, let us first take a look at the Ohio Valley. Here you have a complex river system, with a main stem almost 1,000 miles in length and with 20 major tributaries. Quality conditions in this system reflect the impact of the activities of millions of people and thousands of industries, as well as the influence of a host of natural variations. And to phrase it in the vernacular: Something's always happening on the river!

What happens to water quality in the river has profound implications. Communities must rely on it for a potable water supply. In addition, industrial enterprises on the Ohio River alone require more than 12 billion gallons of water daily for their operations. And one cannot be unmindful of the influence of water quality on aquatic-life resources, recreational pursuits and other beneficial uses of the river.

These considerations led to the recommendation that the Ohio River Valley Water Sanitation Commission look upon the development of a river surveillance and monitoring program as one of the essential elements of interstate water-quality protection. Acceptance of this concept led to the inauguration in 1951 of a network of monitor stations manned by volunteer personnel at municipal and industrial water plants. The scope of this service was then expanded by means of a cooperative contract with the U. S. Geological Survey for systematic monitoring of river quality. More recently, boat and airplane surveillance have become part of the program. And now, with the development of the ORSANCO ROBOT MONITOR system, the foundation has been laid for maintaining day and night vigilance of river-quality conditions at critical points.

New opportunities have thus been created to improve the issuance of interstate alerts to water users, and to otherwise assure the effectiveness of pollution control practice in the Ohio Valley. And Commission headquarters in Cincinnati can better serve as the "intelligence center" for receiving, evaluating and relaying information. Nine years of experience in relaying information on upriver quality changes -- notably those resulting from accidental spills or negligence -- has amply demonstrated the virtues of maintaining vigilance. Issuance of alerts has posted water-plant operators on impending quality changes so that appropriate steps could be taken to deal with unusual situations. In addition, the Cincinnati center keeps state agencies informed on conditions so that corrective action can be promptly instituted.

And finally, the surveillance and monitoring activities are yielding valuable clues for a practical assessment of the behavior of the river system and the performance of waste-control facilities. The data produced by systematic monitoring provides an unparalleled opportunity to match actual conditions against predictions based on design assumptions. This type of evaluation is needed particularly in the Ohio Valley, where stream regimen is complicated by canalization structures, as well as the operation of tributary reservoirs for flood control and low-flow augmentation.

In extolling the virtues of the ORSANCO surveillance and monitoring program it is not suggested that such efforts can be regarded as the alpha and omega of pollution-control practice. The first job of a regulatory agency, of course, is to curb obvious pollution -- raw sewage from municipalities and indiscriminate discharge of industrial wastes. When substantial progress has been made in this direction -- as has been achieved by the eight states in the Ohio Valley -- then a monitoring program assumes significance as a tool for the practical realization of river-quality management.

ACKNOWLEDGMENTS

The ORSANCO ROBOT MONITOR system is based on an original conception of the senior author whose enthusiasms have been generously supported by the commissioners of the Ohio River Valley Water Sanitation Compact. Detailed execution of the project was the responsibility of the junior author, assisted by Carl Schneider, electronics consultant to ORSANCO.

Contractors who engineered and fabricated the units are: Engineering Specialties Co. of Madeira, Ohio; Minneapolis-Honeywell Corp. of Philadelphia; and the Datex Corp. of Monrovia, Calif. Other equipment or consultation on development was furnished by Beckman Instruments Co., Hach Chemical Co., Jarrell-Ash Co., American Telephone and Telegraph Co., Industrial Instruments, Inc., Daystrom, Inc., George D. Philbrick Researches, Inc. and Met-L-Fab, Inc.

The City of Cincinnati Water Works furnished facilities for testing equipment; Dan Enright, supervisor of filtration, and Robert Doepker, chemist, were especially helpful in this phase of the work.

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INSTRUMENTATION FOR CONTINUOUS ANALYSIS OF CONSTITUENTS IN WATER - A REVIEW

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Even a fleeting glance at a text on water analysis, with its long list of constituents and contaminants to be analyzed, is sufficient to give the casual observer some insight into the needs of water management people for continuous analyzers. Water may contain contaminants which are toxic, or odiferous, or unesthetic, or which menace aquatic life or human health. The variety and volume of wastes which industry dumps into our streams require that streams be continuously analyzed so that quality is constantly maintained for the downstream user. Water must be continuously processed for drinking purposes with levels of purification chemicals maintained for the protection of the public's health.

To meet the needs of water management, a number of continuous stream analyzers have been developed. It is the intent of this paper to present a review of the presently available instrumentation with emphasis on the principles involved rather than on manufacturers or on details of design or operation. With the continuing development of new analyzers, it is inconceivable that this review will be complete. It is also our intent that no implications of superiority or inferiority be given as to the merits of any instrument or principle of operation.

At the outset, it would seem wise to define terms. Since this talk is primarily concerned with continuous stream analyzers, let us look for a moment at what we mean. First, let's examine the term "analysis." In this talk, it will refer to the measurement of chemical components in a process stream. Accordingly, the analyzers of which we will speak are those which will measure a characteristic property of chemical materials. Since the term "analysis" implies "how much," we will say then that an analyzer is an instrument which, by measuring a characteristic property of a chemical material, will tell us quantitatively the amount of that chemical material in the process stream.

The term "continuous," as we shall use it, includes not only the constant, instantaneous measurement of a property, but also those analyses which require an increment of time for the final measurement to be made. This latter type of analysis is generally regarded as semi-continuous. The criteria we will use to consider this type of analysis "continuous" is that the instrument itself automatically and routinely samples the process stream and carries out the analysis at set intervals without intervention from operating personnel.

These two factors then give us our basic definition. A continuous analyzer is an instrument which quantitatively measures a constituent in a process stream instantaneously or repeatedly without requiring assistance from operating personnel.

We all know, however, that no instrument will function indefinitely without human assistance. Thus, we must immediately start qualifying our terms. Shall we say, then, that an instrument is continuous if it can run 24 hours without help? Or, should we pick one week as a more realistic figure? Since any figure would rightly be subject to attack, we must look for better qualifying terms. We would propose three criteria to replace any finite time requirement. 1) That the instrument operates sufficiently without attention to economically justify its existence; 2) That the instrument does a better job of analysis than is possible by conventional manual techniques; and 3) That the instrument itself can be used to actuate secondary devices to continuously adjust and control process variables, or activate alarms to warn operating personnel of off-limit conditions.

Finally, our analyzer to be continuous, must have the ability to function satisfactorily under widely varying conditions. In short, it must be sufficiently rugged to withstand exigencies of environment, such as temperature, humidity, moisture, shock, and electrical interference.

Now that we have a definition (if debatable) of a continuous analyzer, let us look at some of the applications for such instrumentation. Generally speaking, the applications fall into two broad categories: 1) Those instruments which assist in water purification and treatment, and 2) Those instruments which are used to detect constituents or contaminants in the raw water supply. We might enumerate some of the constituents which are commonly analyzed. "Standard Methods for the Examination of Water, Sewage, and Industrial Wastes,"[1] embraces a list running from A-acidity to Z-zinc. Some of the more common instrument analyses are for acidity, alkalinity, calcium, chloride, chlorine, color, conductance, fluoride, hardness, iron, oxygen, and turbidity.

With this wide range of components, it would appear that a host of instruments would be required to meet the needs of the sanitary engineer. Indeed, it would appear that instruments are being developed almost daily to fulfill these needs.

INSTRUMENTS FOR CONTINUOUS WATER ANALYSIS

COLORIMETRY

Even a casual examination of the methods of analysis for the constituents in water indicates that colorimetry is one of the most versatile and widely used principles of analysis. Figure 24 depicts the basic elements of a colorimeter. In this discussion, we will be primarily concerned with the absorption of visible light. Visual perception of color arises from the selective absorption of certain frequencies of incident light by a colored object. Other frequencies of the incident light are either reflected or transmitted according to the nature of the object. Figure 25 shows the relation between light transmittance and concentration. In chemical analysis, we are concerned with measuring the amount of light transmitted or absorbed by a solution and relating this to the concentration of some particular ion or compound in the solution.

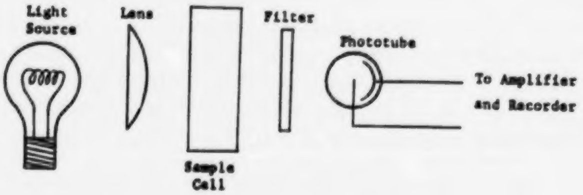


Figure 24. ELEMENTS OF A COLORIMETER.

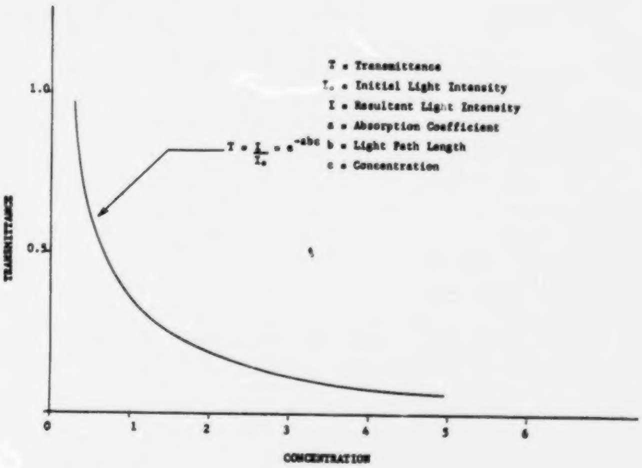


Figure 25. LIGHT TRANSMITTANCE VERSUS CONCENTRATION.

As regards water analysis instruments, we can break down this class of analyzers into two types. First, where portions of the stream is passed through the instrument without any pre-treatment or chemical addition. Figure 26 shows a typical flow colorimeter installation. Here, the instrument measures directly some quality of the stream. An example of its use is in the monitoring of potable water for color. Color may be due to the presence of iron, or from the leaching of vegetable matter. Another important use is in the measurement of turbidity, and, hence, the instrument is useful in the monitoring and control of

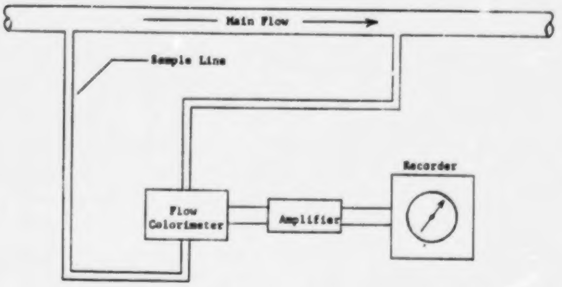


Figure 26. TYPICAL FLOW COLORIMETER INSTALLATION.

coagulation, sedimentation, and filtration processes.

The second type of colorimetric instrument we might term the wet chemical analyzer. Here, reagents are added to the sample to produce a property which can be measured. Although other detecting methods might be employed, colorimetric detection is by far the most widely used. Generally speaking, reagent addition colorimetry can frequently be quite complex enough so to challenge the ingenuity of instrument manufacturers. That some instrument makers have met the challenge is a credit to the industry.

We have said that, basically, colorimetry is concerned with measuring the amount of light transmitted by a solution. Often, however, many problems must be overcome before the sample reaches the photometer cell. Generally, one or more reagents must be mixed, perhaps sequentially, with the sample. Frequently, heating or cooling is required. Almost always, time must be allowed for color development. Precise control of flows or volumes is a necessity. Add to all this the interferences which are frequently inherent in the colorimetric method and you can readily understand some of the problems which face the instrument manufacturer.

Colorimetric wet chemical analyzers may be further divided into two classes: First, the type of instrument which intermittently samples, and, through stepping switches and programming devices, performs the analysis much in the same manner as the chemists would do on the laboratory bench. Figure 27 depicts, schematically, the principle of such an instrument. This automated "chemist in a box" type of instrument measures the sample generally in a vessel with an overflow leg; measures the reagent or reagents in similar vessels, and then permits the sample and reagent to flow through solenoid valves controlled by the programmer to a mixing vessel. Following mixing and holdup for color development (if necessary) the sample is permitted to flow, again through a solenoid valve controlled by the programmer, to the measuring cell. Here, transmission of light by the sample at some selected wavelength is related to the concentration of the analyzed component. This type of instrument has been developed to perform even such a complex analysis as silica in the trace amounts found in boiler feed water. As previously noted, the instrument intermittently samples the stream, and, hence, the analyses are intermittently performed. This is an example of a semi-continuous analyzer.

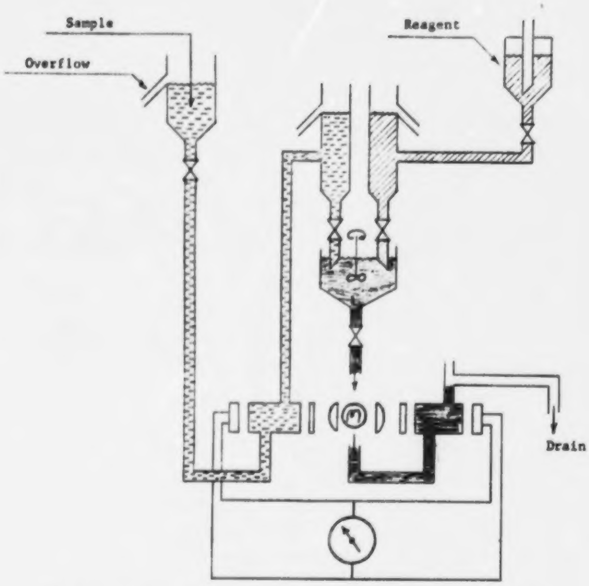


Figure 27. SEMI - CONTINUOUS COLORIMETRIC ANALYZER.

The second type of wet chemical instrument employing the colorimetric principle is the continuous titrator. Such an instrument relies on a constant and continuous flow of sample to which an indicator solution is also added at constant rate. Figure 28 is a simple block diagram showing the flow patterns. Reagent of constant concentration is added at a rate which varies, depending on the concentration of the analyzed substance in the stream being changed as required to maintain a colorimetric endpoint. Light transmitted through the solution varies, depending on whether or not sufficient reagent is being added to pass the endpoint of the titration. The signal from the photocell is used to continuously activate a device which increases or decreases the reagent flow rate in an attempt to make the flow exactly as required to maintain the colorimetric endpoint. Concentration of the substance measured is then related to reagent flow rate.

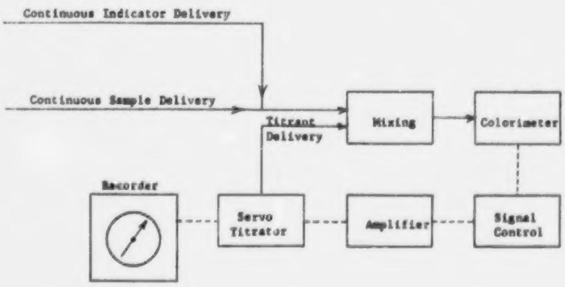


Figure 28. PRINCIPLE OF A CONTINUOUS COLORIMETRIC TITRATOR.

It can readily be seen that this type of analyzer is limited to those analyses which require the addition of a single reagent. In addition, color development must be rapid so that delay time is not introduced which would cause the instrument to cycle. In reality, flow is not maintained to exactly meet the endpoint requirements, but, rather, the instrument hunts around the flow rate where color change takes place. Colorimetric analyzers are, generally speaking, limited to clean, clear samples.

Some examples of water analysis which utilize colorimetric analyzers are: residual chlorine, fluoride, alkalinity, hardness, cyanide, iron, and chromium.

It can be said without serious contradiction that the development of colorimetric analyzers represents a major trend in instrumentation to meet the needs of those concerned with water and water analysis. We can look forward to new and, perhaps, startling developments in this line.

COULOMETRY

Coulometry is an electrochemical principle which finds use in instrument design and consequently is used in water analyzers. Coulometric instruments are, in essence, continuous titrators wherein the titrating reagent is continuously generated in quantity demanded by the analyzed constituent in the stream. Figure 29 is a simple diagram showing the basics of a coulometric analyzer.

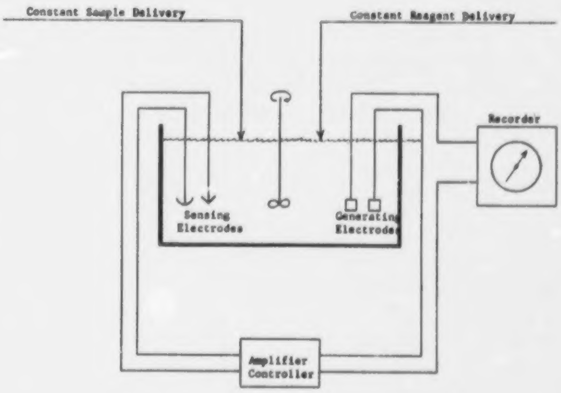


Figure 29. INSTRUMENT EMPLOYING COULOMETRIC PRINCIPLE.

Water and non-reactive reagent are caused to flow through an electrolytic cell. Two pairs of electrodes are contained in the cell; one pair serves as a detecting system while the other pair carries an electrolyzing current to generate the reactive reagent. The detecting electrodes transmit information to a controller which transforms this information into appropriate current delivered to the electrolyzers. Generation of reagent is controlled to the exact endpoint of the reaction, and, thus, concentration of the reactive constituent is directly proportional to current based on Faradays law.

An example of a continuous coulometric titrator is a free chlorine analyzer.[2] Water and reagent containing ferric ions is caused to flow through the electrolytic cell. Current flow reduces the ferric ion to ferrous ion, which, in turn, reacts with free chlorine in the sample. Chlorine concentration, then, is proportional to the current used in generating ferrous ions.

Coulometric titrators are very sensitive devices, and are capable of detecting changes as small as a few parts per billion.

AMPEROMETRY[3]

Instruments for continuous analysis have been developed using the amperometric principle. Again, the chief interest to the water chemist is the residual chlorine analysis. Amperometry employs a fixed voltage on a pair of electrodes. The diffusion current measured at the polarizable electrode is related to the concentration of the substance measured. Figure 30 depicts the flow scheme of an amperometric instrument.

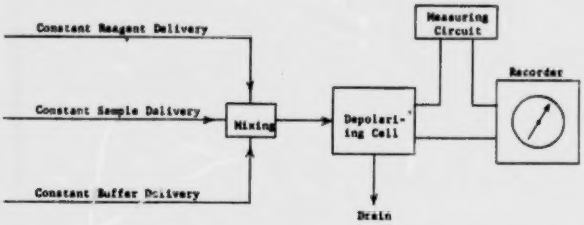


Figure 30. INSTRUMENT EMPLOYING AMPEROMETRIC PRINCIPLE.

In a commercially available instrument, a potassium iodide and a buffer solution are added to the water sample stream containing the residual chlorine. The chlorine reacts with the KI, releasing molecular iodine. Depolarizing action of the iodine alters the current flow through the cell in proportion to the iodine concentration. Thus, the amount of current flow is a function of the original chlorine concentration. Readout is on a recorder, and the instrument is said to be able to detect chlorine at about the 0.01 ppm level.

CONDUCTIVITY[4]

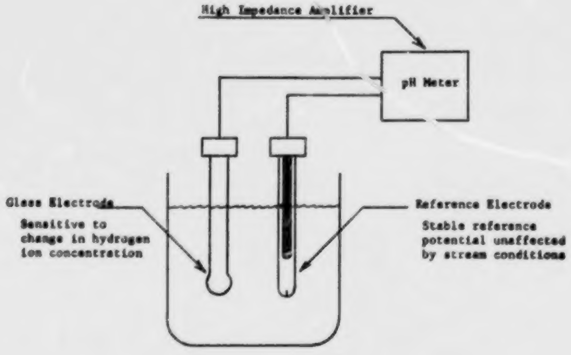
Solutions of electrolytes conduct an electric current by the migration of ions under the influence of an electric field. This phenomena is used as the basis of another type of continuous analyzer, namely the electrical conductivity instrument. In a conductivity cell with two plates of fixed area, and with fixed spacing, the resistance to flow of current is dependent on the concentration of ions in the electrolyte between the plates. However, the resistance depends not only on the total concentration of ions, but also on the types of ions. For example, hydrogen ions have roughly seven times the ion mobility (or ion conductance) as sodium ions, while hydroxyl ions have approximately 2-1/2 times the mobility of chloride ions. Thus, it can be seen that electrical conductivity measurements are nonspecific with regard to analysis of multicomponent electrolyte.

This discussion does not mean to imply that conductivity instruments cannot be valuable tools for the water analyst. This instrument has been used to advantage to follow trends in contamination and electrical conductivity measurements have been related to chloride ion concentration in streams. The measurement of total dissolved solids is commonly done by electrical conductivity.

POTENTIOMETRY

Potentiometric instruments are the granddaddy of stream analyzers. The pH meter is so common and widely used that it requires but the briefest mention here. The pH meter, in effect, is an instrument which analyzes the stream for its active hydrogen ion concentration. Once the hydrogen ion concentration is determined, the analyst can easily determine the hydroxide ion concentration from the ion product constant of water. No matter what else may be in the stream, hydrogen ions and hydroxide ions are always present. Their concentrations are of great importance in effecting such reactions involving flocculation and sewage digestion.[5] Their presence in proper amounts is essential for the destructive oxidation of cyanide wastes. Their presence can affect taste or promote corrosion in pipes.

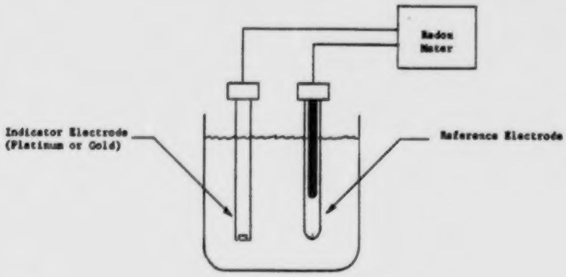
The basics for a pH measuring system are a glass electrode, a reference electrode, and a highly refined amplifier. These are shown in Figure 31. The glass electrode responds only to change in hydrogen ion concentration, and this response is marked by a potential change. To complete the circuit, a reference electrode whose potential is unchanged by stream conditions is used. The pH meter amplifies this very weak signal and makes it useable for readout, recording, or control.


High Impedance Amplifier
pH Meter
Glass Electrode
Sensitive to change in hydrogen ion concentration
Reference Electrode
Stable reference potential unaffected by stream conditions

$$E = E^{\circ} - \frac{RT}{nf} \log H^{+}$$
$$= E^{\circ} - 0.0591 \log H^{+} \text{ (at 25°C.)}$$

Figure 31. BASIC APPARATUS FOR pH MEASUREMENT.

A second instrument using the principles of potentiometry is the Oxidation-Reduction Potential (or ORP) Analyzer.[6] It employs essentially the same principles as the pH meter, as shown in Figure 32, except that an electron-sensitive electrode replaces the hydrogen ion-sensitive glass electrode. This electrode is generally made of a noble metal, such as platinum or gold. This instrument is of particular interest to the water chemist who is concerned primarily with waste disposal. Some of the applications of ORP instrumentation are in the monitoring of streams to detect unwanted industrial waste reductants or oxidants. Two of the most significant industrial waste treatments involving ORP are cyanide oxidation and hexavalent chromium reduction process. ORP measurement also finds useage in sewage treatment processes.[5]



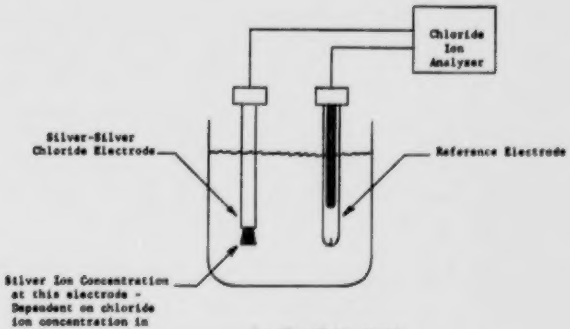
$$E = E^{\circ} - \frac{RT}{nf} \log \frac{(\text{Reductant})}{(\text{Oxidant})}$$
$$E = E^{\circ} - \frac{0.0591}{n} \log \frac{(\text{Red.})}{(\text{Oxid.})} \text{ (at 25°C.)}$$

Figure 32. BASIC APPARATUS FOR OXIDATION-REDUCTION POTENTIAL MEASUREMENTS.

A more recently introduced instrument employing potentiometry is the chloride ion analyzer.[7] It shows promise of becoming a valuable tool for water management people. It uses the same basic equipment as the pH or ORP meter, except that a chloride ion-sensitive electrode is used rather than glass or noble metal electrode. See Figure 33.

It has long been known that a metal in contact with its ions will produce a potential and that potential will depend on the concentration of the metallic ions. This is simply a form of oxidation-reduction potential wherein the metal is the reduced form and the ions are the oxidized form. Thus, if a metal electrode is coated with a sparingly soluble salt containing the anion which is to be measured, the presence of that anion in the stream will control the amount of metallic ions which the metal salt can send into solution and thereby the potential. The potential at the electrode then is determined by the anion concentration in the stream.

The chloride ion-sensitive electrode is made from a mixture of metallic silver and silver chloride salt pressed under extremely high pressure to form a structurally sound billet. This is done because a simply coated


Chloride Ion Analyzer
Silver-Silver Chloride Electrode
Reference Electrode
Silver Ion Concentration at this electrode - Dependent on chloride ion concentration in sample.

$$E = E^\circ - \frac{RT}{nF} \log \frac{(AgCl)}{(Ag^+)}$$

$$= E^\circ + 0.059 \log (Ag^+) \text{ (at 25°C.)}$$

$$(Ag^+) = \frac{K_{sp}}{(Cl^-)}$$

$$E = E^\circ + 0.059 \log (Cl^-) \text{ (at 25°C.)}$$

Figure 33. BASIC APPARATUS FOR CHLORIDE ION MEASUREMENT.

electrode soon loses its coating through abrasion, erosion, or dissolution when placed in a continuously flowing stream.

Along with the silver-silver billet chloride ion-sensitive electrode, the chloride ion analyzer uses a conventional reference electrode and a refined, stable amplifier.

Of the many applications of this instrument, there are several which may be of interest to the water analyst. The instrument is being used to monitor rivers for chloride content as index of stream pollution. It is being used by some industrial plants to monitor or control the disposal of chloride-bearing wastes. An interesting application is that of monitoring sea water intrusion into the delta area east of San Francisco by the California State Department of Water Resources.

Like most instruments, the chloride ion analyzer is not completely free from interferences. For example, strong oxidizing or reducing agents interfere. Chemicals which attack silver or silver chloride, of course, cause difficulties as well as those ions which form less soluble salts with silver than does chloride. Generally, such substances are not found in streams of interest to the water chemist.

DISSOLVED OXYGEN ANALYZER

Dissolved oxygen content of surface waters is frequently of interest to the water chemist. An instrument has been developed[8] to fulfill this need. The operation of this instrument is based on the fact that at equilibrium, the partial pressure of oxygen above a water surface is proportional to the amount of oxygen dissolved in the water. Figure 34 depicts the flow pattern of a commercial dissolved oxygen analyzer.

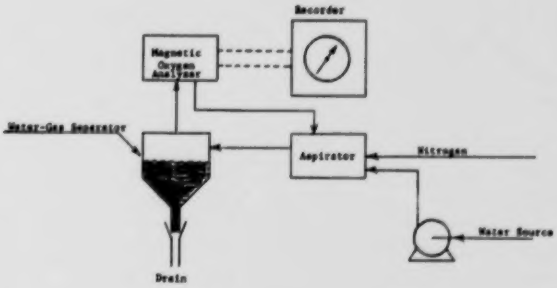


Figure 34. DISSOLVED OXYGEN ANALYZER FOR SURFACE WATERS.

Sample water is pumped into an aspirator where the water is mixed with gas confined in the system. The gas-water mixture is forced into a separator where the gas is separated from the water. Gas is discharged from the separator and flows through a magnetic oxygen analyzer where it is mixed with fresh sample water. The analysis for oxygen itself is based on the well-known paramagnetic characteristic of oxygen.

THINGS TO COME

I would not like to conclude this discussion without a few remarks about instrument developments taking place which may soon bring you new and important analyzers.

In the field of potentiometry, for example, it appears that other specific ion analyzers may be feasible. Glass electrodes have been developed which are sensitive to sodium ion concentration.[9] These electrodes are similar in appearance and construction to pH glass electrodes. Application possibilities for sodium ion analyzers include water softening processes, ion exchange resin technology, and sea water intrusion studies. Other possibilities for specific ion measurement include sulfide, cyanide, and chromate measurement, and these could be of interest in the treatment of plating wastes.

It would appear that polarographic measurement of dissolved oxygen is nearly a practical reality.[10] Such a system was first described by Clark, and the electrode developed is frequently referred to as the Clark electrode. It consists of a probe containing a platinum cathode, a silver anode, and a gas-permeable membrane arranged in a unique manner. Figure 35 is a schematic diagram of the oxygen electrode system. the platinum surface is pressed firmly against the inside of the membrane, and is electrically connected to the silver anode by a chloride-containing electrolyte which fills the cell. About 0.6 volts potential is applied to the cell. The potential is too low to cause discharge of hydrogen and, in the absence of gases reducible at this voltage, the cell merely polarizes. However, if a reducible gas is present in those passing through the membrane a current flows in the cell proportional to the partial pressure of the gas. Oxygen is the most common gas which meets the requirement.

The current can be measured by a series of microammeter, or potentiometrically, or most accurately by means of a D.C. feedback amplifier. Response time to change in oxygen concentration is quite rapid, and is dependent on membrane thickness and temperature. Current is also temperature dependent, and, at present, this is a limiting factor in the usefulness of the electrode. However, Carritt and Kanwisher[11] report on the use of the polarographic electrode with temperature compensation.

Interesting work has been done using the polarographic technique by Dr. Eye, et al,[12] at the University of Cincinnati. He reports the use of the polarographic oxygen electrode to be as accurate and reliable as the standard Winkler Method in determining dissolved oxygen in B.O.D. samples.

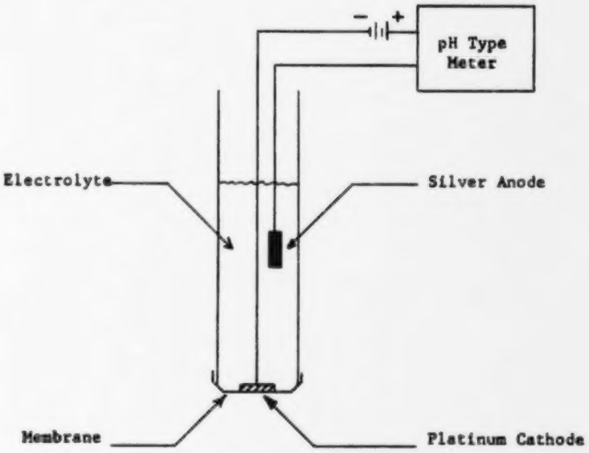


Figure 35. THE POLAROGRAPHIC OXYGEN ELECTRODE SYSTEM.

Perhaps the most dramatic developments to come will be in the field of wet chemical analyzers. Recent trends in the process industries indicate a growing need for specific component analyzers wherein it is impossible to identify the component by some direct chemical or physical property. In this type of analyzer, reagent is added to cause a reaction which will produce a measureable quality which can be related to the concentration of the desired component in the sample stream. We have mentioned this type of analyzer in our discussion of colorimetry. However, here colorimetry is the method of determining the concentration of the reaction product. It can be expected that other principles will be used, such as potentiometry or amperometry, for reaction product determination.

As previously noted, many of the present wet chemical analyzers use semi-continuous, "automated chemist" techniques. Quite complex analyses are made with such instruments. It can be expected that new continuous analyzers will be developed involving even more complex reagent addition systems. Much of progress in this field will depend on the development of reliable, precision metering pumps capable of delivering constant flows for long periods of time without excessive maintenance. Such pumps will have to be capable of pumping not only clean, solids-free reagents, but also samples which may often be considerably less than clean. It appears that considerable progress has been made recently in pump design. Reliable, accurate metering pumps will bring greater simplicity to wet chemical analyzers, along with new versatility to make possible more complex analysis.

CONCLUSION

In considering the variety of instrumentation presently used for continuous water analysis, we cannot fail to realize that many analyses are not being made continuously simply because instrumentation is not available. It is probable that some of the complex analyses will be simplified, or new methods developed. This will permit the use of instrumentation using present techniques. It is a certainty that new analyzers will be developed to carry out more complicated analyses than are presently being done.

It is in the realm of new instrumentation that a greater understanding is needed for the problem of both the instrument user and the instrument maker. The instrument user wants an analyzer which once installed can be plugged in and essentially forgotten. The instrument maker would like to provide just such an analyzer. Unfortunately, neither is likely to realize this ambition. It must be realized that many of the constituents of interest to the analyst exist in quantities sometimes of a few parts per billion or million, and, frequently, they are surrounded by a host of interfering substances. It must be realized that, frequently, the analysis brings on infinitesimally small signals. For example, the current in a pH electrode system may be on the order of 10^{-10} to 10^{-12} amperes. It must be realized that seldom is an analysis free of interference; that electronic components are not free from failure; that a muddy stream will coat optical cells. An automobile will not run long without lubrication or tune-up by skilled mechanics. So, too, an instrument which is expected to do a much more exacting job deserves not only the routine maintenance, but the occasional tune-up by the skilled mechanic.

The instrument maker must know the needs for instrument users. To exist, he must have the opportunity to realize a profit. He cannot afford to spend vast sums for development of instrumentation for a limited market. For this very reason, the most refined instruments available are those which find application in many industries. Note, for example, that pH or infrared, or gas chromatography instrumentation is used by many industries. Where special needs arise, cooperative efforts on the part of maker and user could be utilized to solve specific problems.

The need and value of continuous stream analyzers for water analysis is obvious. Increased understanding and cooperation on the part of water management and instrument designer will, in the future, make possible new and better instrumentation which will serve the common good.

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A NEW PORTABLE INSTRUMENT FOR THE CONTINUOUS AUTOMATIC COLLECTION OF WATER SAMPLES

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Increased awareness of the problems of stream pollution, combined with a desire to retain self regulation as far as possible, have greatly stimulated industry's interest in the allied fields of waste water sampling and analysis.

Apparatus for the testing and analysis of waste water is to be found in the laboratory of almost any well equipped industrial plant. The actual accumulation of truly representative samples, however, has posed many vexing problems, as no analytical method can be more accurate than the statistical accuracy of the sample accumulation.

It soon became apparent that the so-called "grab sample" method was not only lacking in the required statistical accuracy; but also very costly in man power on a cost per sample basis on a continued waste water program.

In their paper, "Planning a Waste Water Survey", Hedgepeth, Gabaccia, et al. cite an ingenious battery operated sampling station. This device consists of a small DC centrifugal pump operated from an automobile storage battery. In order to reduce the rather high delivery of such a pump to the two to three gallons per day required, the pump is operated on a fourteen minute off-one minute on cycle. This cycle is controlled by a repeat-cycle timer also operated from the storage battery. The timer has an adjustable cam in order that the operator might regulate the pumping period and hence the sample volume collected. Such a device, albeit independent of power lines and relatively portable, lacked statistical accuracy for a truly accurate analysis. There was the possibility of small sudden discharges going uncollected.

For descriptions of the many other sampling devices developed by the Chemical Industry, the reader is referred to any of the several publications of the Sewage and Industrial Waste field.

Through the development and manufacture of the special sequence timers employed on many of these devices, Brailsford & Company, Inc. became interested in the field of effluent sampling and undertook the development of a more portable instrument, bearing in mind the combined needs of power economy and sampling accuracy. Such a sampler it was felt, should function on readily obtainable dry cell batteries with maximum possible service life between changes. It should also be sufficiently light and portable for spot sampling during stream survey work. In contrast to much of the existing equipment, the instrument would accumulate a continuous sample permitting more accurate compositing and analysis.

Consideration of numerous methods of sample accumulation disclosed the slow moving oscillating cylinder pump to be the most promising. As the piston of such a device reciprocates, the cylinder is caused to oscillate about a shaft or pivotal point. This action brings the single cylinder port into alternate register with the inlet and exhaust ports in the valve plate. Such a design has the advantage of simplicity, having as it does only two moving parts. The wiping action of the port alignment is inherently self-cleaning, a most desirable feature in the sampling of effluent containing concentrations of suspended matter. The pumping mechanism is constructed of rigid, high-density polyethylene of the MARLEX series 5000, permitting the sampling of sewer effluents containing strong caustics as well as organic solvents.

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* The writers desire to acknowledge with thanks the assistance of Dr. M. V. Anthony of the Stauffer Chemical Company and Mr. A. G. Gabaccia of the American Cyanamid Company in the development phases of this instrument.

Adequate power for lifts of the order of six feet are provided by a Brailsford Type AG motor of patented design. In this motor, of the permanent magnet rotor type, a fixed coil supplies flux to the field structure. Periodic reversal of this field is attained by a contactor on the rotor shaft proper. Speed regulation of approximately 1% throughout the life of the batteries is provided by a built-in governor. This motor will not start if the batteries are connected in reverse; a safeguard against accidentally pumping in reverse. The normal service life of the motor is in excess of two thousand hours of continuous operation. Electric power is provided by three #6 dry batteries, a unit selected for its combination of high capacity and easy obtainability from local dealer's stocks. The average power consumption through the pumping cycle is about 0.025 amperes at 4.5 volts. This, incidentally, is about one-tenth the power consumption of the average flashlight and provides an average battery life of two to three thousand hours at a lift of four to six feet. The motor-pump assembly is pre-set at the factory for a delivery of 1.8 gallons per day. An automatic float cut-off is provided to preclude the chance of overflow if the sampler is not serviced on time. The entire mechanism, including sample receptacle is housed in a case of 11 ply birch plywood covered with mil-spec heat reflecting lacquer. In use the plastic inlet tube is led out through a port in the bottom of the case. This permits the case to be locked. Field experience has shown this case to be exceptionally durable for both stream and sewer sampling work. Many permanent installations, however, provide a protective shelter for the instrument to eliminate the chance of tampering.

As is the case with any pumping mechanism, the Model DC Effluent Sampler is affected by certain well defined physical phenomena which may be subjected to rigorous laboratory testing as well as empirical determinations in the field. During the development phase, tests were conducted on the effects of lifts higher than the recommended 4-6 feet to determine the effects on battery and motor life and the characteristics of the samples so accumulated. As the lift of the Sampler is increased to a practical limit of about fourteen feet, motor and battery life sharply decline. The effect of these high lifts may be easily understood when one realizes that raising a two gallon sample to a height of ten feet entails the expenditure of 140 foot pounds of energy. This testing also disclosed a pronounced tendency for dissolved gasses to effervesce out of solution in lifts in excess of six feet; an effect that would seriously impair the results of tests for dissolved oxygen or other gasses in solution. The sampler is, however, sufficiently portable to be placed conveniently near the level of the sample to provide an optimum battery life of three thousand hours and a motor life of approximately six months.

Any field sampling installation encounters a great variety of suspended fibrous or particulate matter differing in individual size and weight. As previously stated, the wiping nature of the port-transfer action eliminates the chance of flap or ball valves becoming jammed. The main determinant in the handling of suspended solids is a question of particle mass rather than absolute turbidity per se. As a rule of thumb, the amount of loss may be determined by the amount that will settle out of the intake line in the approximately one minute of the discharge phase of the pumping cycle. This problem too, may be, in large part eliminated by placing the sampler as near stream level as possible. Where large amounts of relatively heavy material are present in the sample, use of the following device has provided material pickup of close to 100%. A 500 cc wide mouth bottle is equipped with a two-hole rubber stopper; one hole of which has a glass tube terminating 1/4" from the bottom of the bottle. The other end of the glass tube projects slightly above the stopper. The end of the plastic sampler inlet tube is attached to this and the whole assembly submerged in the sample stream. At the end of each 24 hour sampling period, the contents of the wide mouth bottle are added to the contents of the regular sample container.

The field experience gained with the Model DC Sampler has indicated the need for the development of other models to meet certain specific needs that cannot be handled with the general purpose Model DC. Some of these are:

1. An explosion-proof model with the power supply and motor hermetically enclosed, permitting use in the sampling of sewers and other locations that contain flammable or explosive gasses.

2. A sampler, explosion-proof as per the above specifications, providing means for maintaining the sample under a positive pressure of about 5" of water column to prevent the evaporation of highly volatile fractions in the sampling of petroleum refinery wastes. This type of sampler would also be useful in dissolved oxygen studies.

3. A portable sampler for use on effluents containing very large amounts of suspended or floating matter such as is found in paper plant wastes or in the sampling of raw sewage.

4. A permanent sampling station where an AC power line is conveniently available. Such a device would employ the Brailsford Valveless Pumps as used in the Model DC. This sampling station would be designed to suit the individual installation and would provide means for dividing the sample into 24 equal quantities, each representing one hour's flow of effluent.

Other sampling devices will be investigated as the demand warrants.

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MONITORING STREAM QUALITY

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From the standpoint of Public Health one of the chief considerations given a potable water source is the chlorine demand. On this will be based one of the treatment processes. The value of chlorination in maintaining safe potable water supplies has been well established. Of equal importance in industrial as well as potable water treatment is the ability of chlorine to control slime growths, oxidize iron and manganese to facilitate their removal, aid coagulation, bleach color, and remove taste and odors. Before maximum benefits from chlorination can be assured, it is imperative that the chlorine demand be determined.

Another parameter of water quality, the importance of which has been scarcely explored, is the Oxidation-Reduction Potential of water. Equipment for the continuous monitoring and recording of chlorine demand and O-R Potential for indications of stream quality will be discussed.

DEFINITIONS

It would be well before proceeding further to review the definition of chlorine demand. It is the amount of chlorine that must be added to water to produce a measurable residual of a specified type, after a given contact time, at a specific temperature and pH value. It is expressed as milligrams per liter, or more frequently as parts per million.

Of these the most important condition is the type of residual. That which is uncombined with ammonia nitrogen is called free available residual chlorine. That which has combined with ammonia or organic nitrogen is combined available residual chlorine, otherwise known as chloramines. The sum of these two types is total available residual chlorine. In future references they will be called "free residual", "combined residual", or "total residual". On a practical basis chlorine demand is expressed as that to produce a free residual or that to produce a total residual.

Free residuals are obtained when chlorine is added to water free of ammonia or when sufficient chlorine has been added to oxidize the ammonia nitrogen and prevent the formation of combined residual. The latter is called "break-point" and is illustrated in Fig. 36.

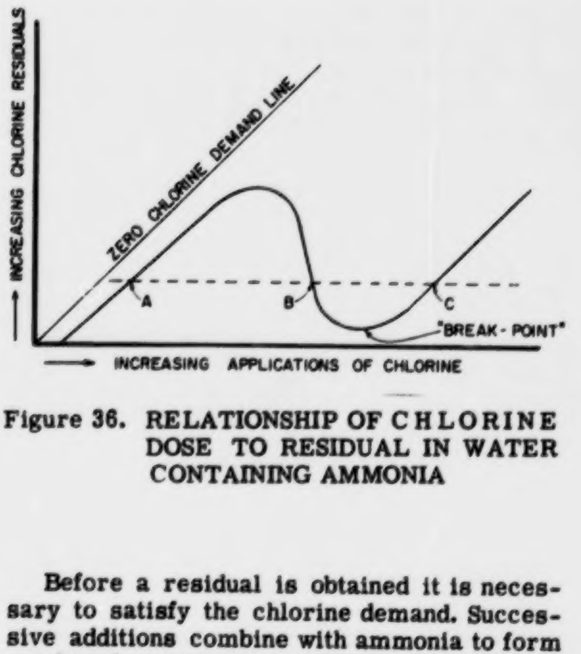

Figure 36. RELATIONSHIP OF CHLORINE DOSE TO RESIDUAL IN WATER CONTAINING AMMONIA

Before a residual is obtained it is necessary to satisfy the chlorine demand. Successive additions combine with ammonia to form combined residuals in increasing amounts until sufficient has been added to start oxidation of the ammonia nitrogen. When this point is reached, the residual level decreases sharply to the break-point, the point where the ammonia nitrogen will have been reduced to a minimum figure. Successive additions provide increasing amounts of free residual.

To appreciate fully the problems involved in recording chlorine demand, it should be noted that three different chlorine doses (points A, B, and C) result in the same magnitude of total residual. At point "A" and "B" the residual will be all combined and at point "C" it will be essentially free residual.

CHLORINE RESIDUAL RECORDERS

The principal piece of equipment on which demand recording depends is a chlorine residual recorder. A colorimetric analyzer using orthotolidine is subject to the errors of the Orthotolidine method and would not be suitable for this application. An amperometric cell is satisfactory for recording residuals in water and is free of interference from color, turbidity (within limits), iron and manganese. In this cell bimetallic electrodes produce a current in proportion to residual chlorine in the water. By adding selected reagents in the sample flow it is possible to record either free residual or total residual.

RECORDING CHLORINE DEMAND

One system for recording chlorine demand measures the difference between a predetermined and fixed dose of chlorine and the resulting residual. Equipment for this is shown schematically in Figure 37. In this system a measured volume of sample water is passed through the injector of a chlorinator. A water pressure regulating valve and the orifice of the injector provide a regulated flow through the chlorinator. Chlorine is added in excess of that required to satisfy the demand. The resulting residual chlorine is measured with a residual cell. The demand is the difference between the fixed dose and the recorded residual and is recorded directly in ppm as chlorine demand. If remote recording is desired, an indicating meter is used at the cell location for calibration purposes and an electrical signal transmitted to the recorder.

This system is simple, relatively inexpensive, and can be adapted to any desired contact time by the addition of a contact tank between the chlorinator and the residual cell. A disadvantage to this system is that only the

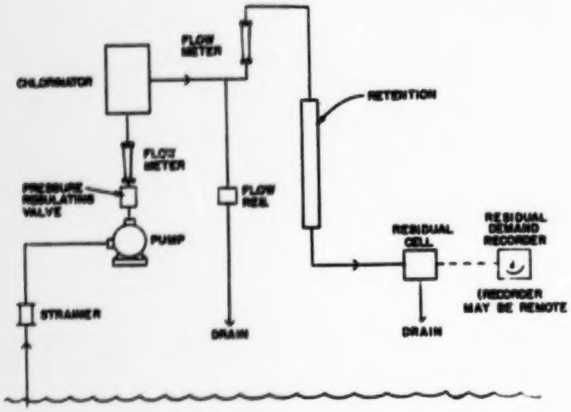
CHLORINATOR
FLOW METER
RETENTION
FLOW METER
PRESSURE REGULATING VALVE
FLOW REG.
PUMP
RESIDUAL CELL
RESIDUAL DEMAND RECORDER
STRAINER
(RECORDER MAY BE REMOTE
DRAIN
DRAIN

Figure 37. SCHEMATIC ARRANGEMENT OF EQUIPMENT FOR MEASURING CHLORINE DEMAND BY DIFFERENCE BETWEEN DOSE AND RESIDUAL.

demand required to produce a free residual can be measured. A residual cell equipped and calibrated for measuring total residual would measure both free and combined residual without differentiation. There is no means by which the cell could determine which type of residual (A, B, or C, Figure 36) it was recording. Either type may be present, depending on variations in the ammonia content. The cell may be calibrated to record only free residual, however.

The amount of chlorine applied must always be in excess of the maximum expected demand. The cost of chlorine used is insignificant. Of some importance is the fact that at periods of low demand the relatively large amount of chlorine applied and the resulting high residual may react with more organic material than would be the case if lesser amounts had been used. This increases the demand and reduces accuracy to some degree.

In water low in alkalinity the relatively large amounts of chlorine would lower the pH beyond that experienced in normal chlorination procedures. This would also have the effect, in most cases, of accelerating the reaction with organic matter to increase demand. The use of hypochlorite solution instead of chlorine would not solve this problem because the excess caustic used to stabilize the solution would increase the pH and merely reverse the direction of the error.

A second system shown schematically in Figure 38 is more complex. It is not subject to the disadvantages of the first but requires more equipment. A flow regulator is used to maintain a constant sample volume through the pump and a chlorinator injector. Chlorine is added to the sample in the injector and a measured portion of the flow is diverted through a retention coil to a residual cell. The remainder goes to waste.

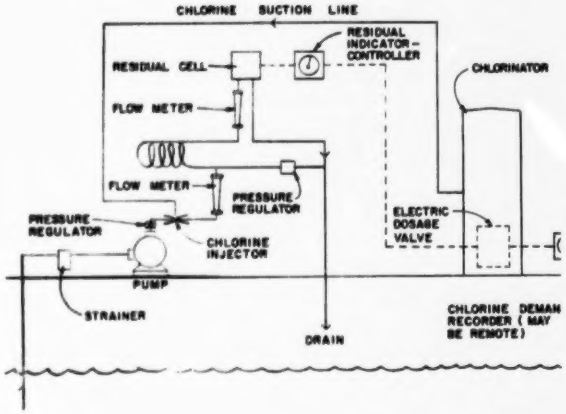
CHLORINE SUCTION LINE
RESIDUAL INDICATOR-CONTROLLER
RESIDUAL CELL
CHLORINATOR
FLOW METER
FLOW METER
PRESSURE REGULATOR
PRESSURE REGULATOR
CHLORINE INJECTOR
ELECTRIC DOSAGE VALVE
PUMP
STRAINER
DRAIN
CHLORINE DEMAN RECORDER (MAY BE REMOTE)

Figure 38. SCHEMATIC ARRANGEMENT OF EQUIPMENT FOR MEASURING CHLORINE DEMAND BY THE DOSAGE REQUIRED TO MAINTAIN A FIXED RESIDUAL.

The signal from the cell actuates a residual indicator-controller. The controller is set to maintain a fixed residual. When the residual deviates from this preset figure, a signal to an electrically operated dosage valve in the chlorinator increases or decreases the chlorine feed rate to maintain the residual at the preset figure.

A potentiometer linked to the dosage valve transmits a signal to a recorder. Since the volume of sample flow is constant, this recorder is calibrated in parts per million chlorine required to maintain the preset residual, in other words, the chlorine demand of the water plus the preset residual.

Control in this system is maintained in a closed loop. As the demand decreases the residual tends to increase and the controller reduces the chlorine feed. The decreased feed rate corrects the residual value. The reverse is true if the demand increases. The closed loop (residual cell-controller dosage valve - sample - and back to the cell) insures continual correction, as required.

In this system the cell can be arranged to differentiate between free and total residual and the controller set to maintain either one selected. The controller plays an important part here in keeping the residual constant and preventing massive residuals to occur. Where the demand to a combined residual is desired, there is no opportunity for the residual level to climb to a point where the ammonia nitrogen is oxidized, causing a change from a combined to a free residual. Hence, the demand to a preset free or total residual can be recorded. The control loop provides means by which the system can maintain itself on either setting. A disadvantage, however, is that to be effective the time lag in the control loop must be limited to approximately five minutes. This is not a serious limitation.

No excess of chlorine is used beyond that required and the effect on pH and alkalinity would be the same as chlorination on a plant scale. A wide range of demand changes can be recorded without the limitations of the first system described. The second system, however, requires more equipment and is more costly to install.

Neither of the systems described can be considered as laboratory equipment. Both are composed of components in regular and continuous use in chlorination of water. The selection is based on the assumption that a 115 volt power supply will be available. No hydraulic or air operated devices or signals are used. On-site or remote recording may be employed, as well as alarms for high or low preset limits. Reagent and chlorine supplies need not be replenished more frequently than once a week and 7-day charts for the recorders are available.

Equipment of this nature should be checked daily. Less frequent servicing can be tolerated. Malfunctions may be easily detected from the chart records. Calibration requires only a few minutes.

OXIDATION-REDUCTION POTENTIAL

A change in O-R Potential in water indicates a change in water quality. Beyond this little has been established. Potential monitoring has been used in iron removal plants to maintain the valence of iron in the ferric state. The same may be possible for manganese. O-R Potential measurement is in general use in metal finishing waste treatment and to a lesser degree in sewage treatment.

Difficulty in correlating potential with dissolved oxygen, B.O.D., C.O.D., or even chlorine demand has discouraged many from realizing that it is a parameter of water quality in its own right.

We have found that the potential of water in surface streams can vary 200 mv to 300 mv in an hour. We know that water of good quality has a higher potential than water of a lesser quality. We know that chlorination increases potential and that dechlorination reduces potential. We know that septic conditions in a stream can be readily detected by measuring its O-R Potential.

We have, in potential measurements, a tool for measuring stream quality that should be explored. The equipment has been developed and is in daily use on other applications. A monitoring station would require only a pump to provide a continuous sample to a flow-through potential cell. It it shown schematically in Figure 39. The recorder could be local or remote.

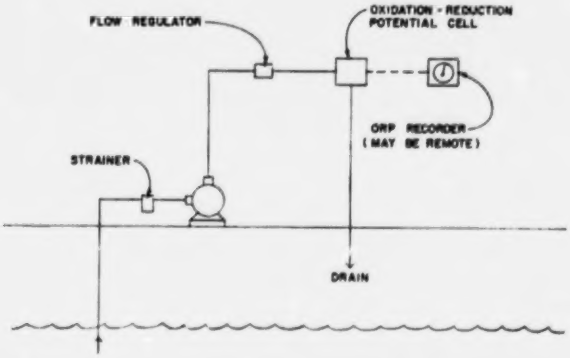
FLOW REGULATOR
OXIDATION - REDUCTION POTENTIAL CELL
ORP RECORDER (MAY BE REMOTE)
STRAINER
DRAIN

Figure 39. SCHEMATIC ARRANGEMENT OF EQUIPMENT FOR RECORDING O-R POTENTIAL OF WATER.

SUMMARY

Two types of equipment arrangements have been described for the continuous determination and recording of chlorine demand in water. Both consist of units which are in use presently for chlorination practices. Advantages and disadvantages of both have been discussed.

To obtain true values of chlorine demand, it is necessary to consider the complex reactions that occur when chlorine is added to water. These reactions have been described.

Oxidation-Reduction Potential measurements can be of value in stream quality studies. Equipment for this has also been described.

AUTOMATIC INSTRUMENTATION FOR WATER ANALYSIS

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With our expanding population and industrial growth, there has naturally been a tremendous increase in our water consumption. This increase in consumption has put a heavy burden on our actual water resources. It is only natural that our major source of water supply, the natural rivers and lakes of our country, would become increasingly polluted with industrial wastes and sewage. In order to prevent such a pollution, it has become more important to monitor continuously the quality of our surface waters and effluent from our domestic and industrial waste disposal systems.

As water treatment problems and the methods for their solution have grown more complex, there has arisen the need for a more accurate analytical determination, not only in laboratory and research analysis, but also in routine plant control.

Furthermore, the enactment of anti-pollution laws by most of our states has additionally emphasized the need to develop satisfactory automatic analyzers to control the quality of effluent from waste disposal systems.

This paper covers the description and discussion of commercially available instruments for automatic analysis of surface and treated waters used for industrial and domestic purposes. Included are instruments for measuring dissolved oxygen, surface tension, residual chlorine, turbidity and traces of various chemical impurities which may contaminate water supplies.

DISSOLVED OXYGEN

It is very important to measure the dissolved oxygen content of water supplies and waste plant effluent in order to determine the degree of pollution of these waters. The standard procedure to determine dissolved oxygen in the laboratory is the Winkler Method. However, this is too slow and tedious and can be used only for routine intermittent analysis. Because of the importance of this measurement there has been a noticeable activity in recent years to develop suitable oxygen measuring electrodes and other types of automatic instruments.

The Hays Dissolved Oxygen Meter (1) has been very successfully used for monitoring dissolved oxygen in effluent from waste disposal systems as well as rivers and streams.

Figure 40 is a schematic diagram of the Hays Dissolved Oxygen Instrument. The water sample flows through an aspirator where it is thoroughly mixed with the gasses combined in the system and then through a centrifugal separator. At this separator, the water is discharged to drain and the gas flows to a paramagnetic type oxygen analyzer where the concentration of oxygen in the mixture is automatically measured. From the oxygen analyzer, the gas sample passes back to the aspirator where it is mixed with fresh sample water to complete the gas sample flow loop.

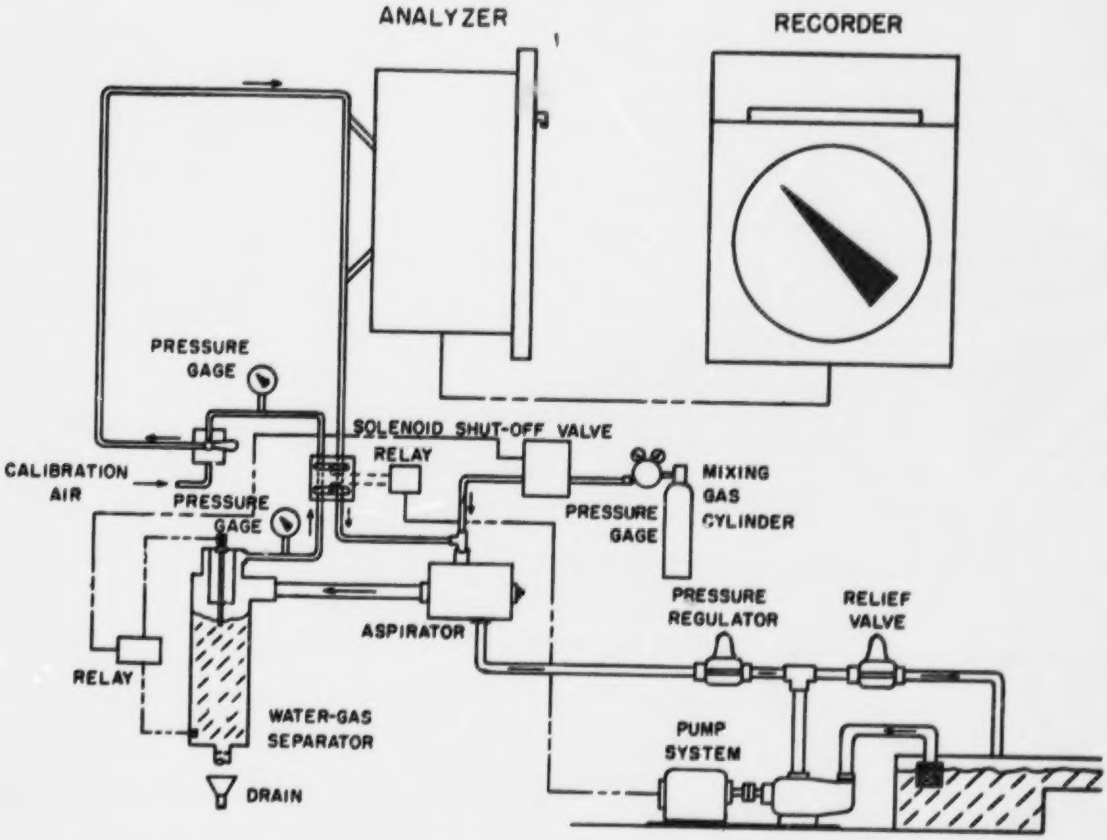

ANALYZER
RECORDER
PRESSURE GAGE
SOLENOID SHUT-OFF VALVE
RELAY
CALIBRATION AIR
PRESSURE GAGE
PRESSURE GAGE
MIXING GAS CYLINDER
ASPIRATOR
PRESSURE REGULATOR
RELIEF VALVE
RELAY
WATER-GAS SEPARATOR
PUMP SYSTEM
DRAIN

Figure 40. SCHEMATIC DIAGRAM OF HAYS OXYGEN ANALYZER.

It must be emphasized that this is a completely closed gas loop, but because of Henry's Law[2], the oxygen content in this gas stream will always be proportional to the amount of oxygen dissolved in the sample water. In order to maintain the water level constant in the water-gas separator, an electrode system is used which controls the flow of a small quantity of nitrogen gas into the system.

Perhaps the most unique feature of this arrangement is the ease of calibration. Simply by opening the three-way air valve, atmospheric air is permitted to pass through the magnetic oxygen analyzer which, having a fixed oxygen content, is, therefore, a very convenient calibration standard.

Perhaps the most noteworthy advantages of measuring dissolved oxygen by this principle is that the analysis is not affected by temperature, salt content, pollution, barometric pressure or the dissolved nitrogen content of the water. The instrument requires very little maintenance. It is reported that the accuracy is better than plus or minus 2% of full scale, and the speed of response is fast, being in the order of 62.5% of full scale calibration in approximately 100 seconds. Further advantages are that no reagents are required, and the consumption of nitrogen gas used to maintain level control is very small. Depending on the dissolved oxygen content of the water, a standard 220 cubic foot nitrogen tank will last from between four months to two years.

Considerable work has been done to measure the oxygen content of water by electrochemical analysis. Dr. S. Toedt in Germany[3] has done much work with electro-chemical methods for measuring dissolved oxygen. In this method he used zinc and gold electrodes immersed in an electrolyte of sodium chloride. A small voltage was maintained by means of a battery across these two electrodes and the current which was passed by the system is calibrated in terms of the dissolved oxygen content of the water. However, these electrochemical methods of measuring dissolved oxygen have not been too successful since other dissolved compounds can produce interferences in this method. Furthermore, calcium bicarbonate causes serious trouble by encrusting the surface of the gold cathode.

The Beckman Instrument Company[4] manufactures an oxygen measuring electrode of a polarographic type. This is a very simple device and can be used to measure dissolved oxygen, and is one of the more recent developments in oxygen measuring electrodes.

Figure 41 is a schematic diagram of the Beckman Oxygen Electrode. This cell consists of a silver anode and a platinum cathode immersed in a potassium chloride electrolyte contained inside a glass tube. The bottom of this tube is sealed with a gas permeable plastic membrane and the platinum cathode is held tightly against the inside of this membrane.

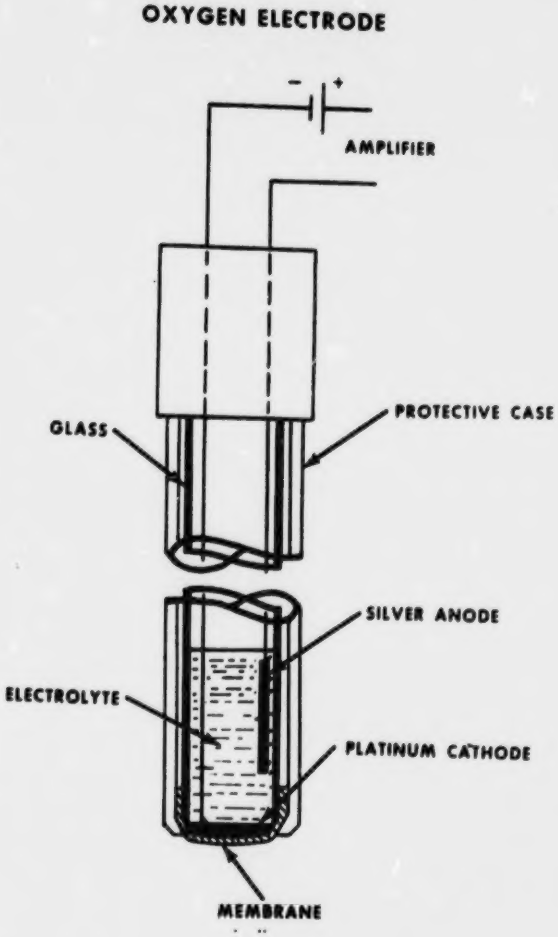


Figure 41. BECKMAN OXYGEN MEASURING ELECTRODE.

A potential of about 0.6 volts is maintained across this electrode system which is too low to cause a discharge of hydrogen, and in the absence of any reducible gases the cell merely polarizes. However, if a reducible gas such as oxygen is present in the electrolyte, a current flows in the cell proportional to the partial pressure of the gas. Therefore, when this electrode is immersed in a water sample containing oxygen this oxygen will then permeate the plastic diaphragm and the current will flow in the cell proportional to the oxygen concentration in the water sample. Because of the gas permeable diaphragm or membrane, the electrode system is only sensitive to dissolved gas and is not affected by the presence of easily reducible ions in the water solution.

Perhaps the most serious drawback to such polarographic methods in that the results are greatly influenced by temperature. For example, at a given oxygen content an error of 5% per degree centigrade will be obtained at room temperature. Therefore, to obtain a precision of plus or minus 1%, it would be necessary to compensate for temperature changes with a precision of plus or minus 0.2° C.

Dr. Dayton Carritt[5] of the Johns Hopkins University has done considerable work with a polarographic electrode utilizing silver-silver oxide reference electrode and a thermistor for temperature compensation. This electrode is now being manufactured by Jarrell-Ash[6].

Figure 42 is a cross-sectional view of the Carritt Dissolved Oxygen Electrode. The Carritt Electrode is quite simple in construction, and consists of an epoxy plastic rod around the circumference of which is a silver-silver oxide reference electrode. At the very end of the electrode is located a small platinum electrode. Imbedded in the plastic epoxy casting is a small thermistor to compensate for temperature changes.

A 0.5 N potassium hydroxide solution is used as an electrolyte which is contained in the space between the probe and a thin polyethylene membrane covering the end of the probe.

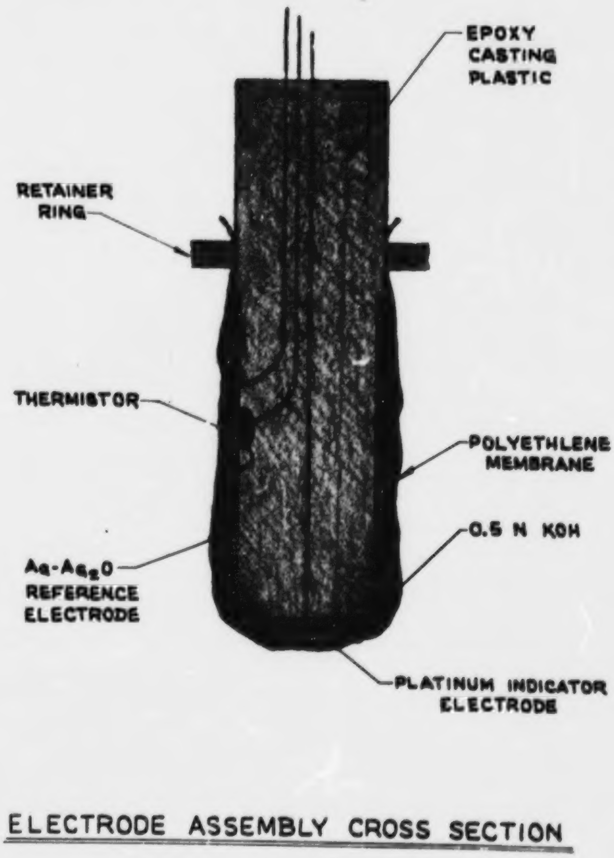

EPOXY CASTING PLASTIC
RETAINER RING
THERMISTOR
POLYETHLENE MEMBRANE
0.5 N KOH
Ag-Ag$_2$O REFERENCE ELECTRODE
PLATINUM INDICATOR ELECTRODE
ELECTRODE ASSEMBLY CROSS SECTION

Figure 42. JARRELL-ASH DISSOLVED OXYGEN ELECTRODE.

The principle of operation of this electrode is quite simple. The polyethylene membrane is permeable to the dissolved oxygen and permits the passage of oxygen to the platinum electrode where it is reduced to hydroxyl ions under operating conditions. A voltage of 1.1 volt is maintained across this cell and the current generated is proportional to the dissolved oxygen concentration in the water. This oxygen electrode has performed very satisfactorily in sea water, fresh water, sewage and even gas streams. Chlorine, hydrogen sulfide acids and bases show no measureable effect on the performance of this electrode. This electrode has been highly successful for use in performing field surveys of streams and oceans. One of its earliest uses was to obtain a vertical oxygen profile of the Chesapeake Bay.

SURFACE TENSION

In determining the quality of a water supply, it would be convenient if we could measure the quantity of surface active substances present in the water since the presence of these substances is usually an indication of the presence of other impurities resulting from pollution of the water supply.

A very convenient way to determine the presence of surface active substances is to measure the surface tension of the water. However, most surface tension measuring instruments are more of a laboratory nature and too delicate to be automated and used for automatic industrial use. It is intended to describe here a completely automated surface tension instrument which has been developed in Germany by Dr. Otto Hettche[7] and Karl Schultze of Hamburg, Germany, and is being manufactured by the firm of Bran & Lübbe[8] also of that city. In conjunction with the latter firm, the Milton Roy Company will make trial installations in this country. The first installation being on the Ohio River.

Two of these instruments have been operating on the Elbe River at Hamburg, Germany, monitoring the surface tension of this river water which is highly contaminated with syndets and considerable quantities of other surface active products which can be traced back to industrial wastes from Middle German plants and deteriorated organics from the tributaries of the Elbe River. It is interesting to note from reports received from Germany on the operation of this instrument that the surface tension of the river water and the dissolved oxygen of the stream run parallel. When the tide is going out, both the surface tension and the oxygen content decrease while with a rising tide, both show an increase in value.

The operation of this surface tension measuring instrument is based on the well known ring lifting method. The instrument automatically measures the force required to lift a small platinum duNöuy ring from the surface of the water sample. Figure 43 is a schematic diagram which illustrates the operation of this instrument. The various steps of this measuring operation are controlled automatically and one analysis is performed every six minutes.

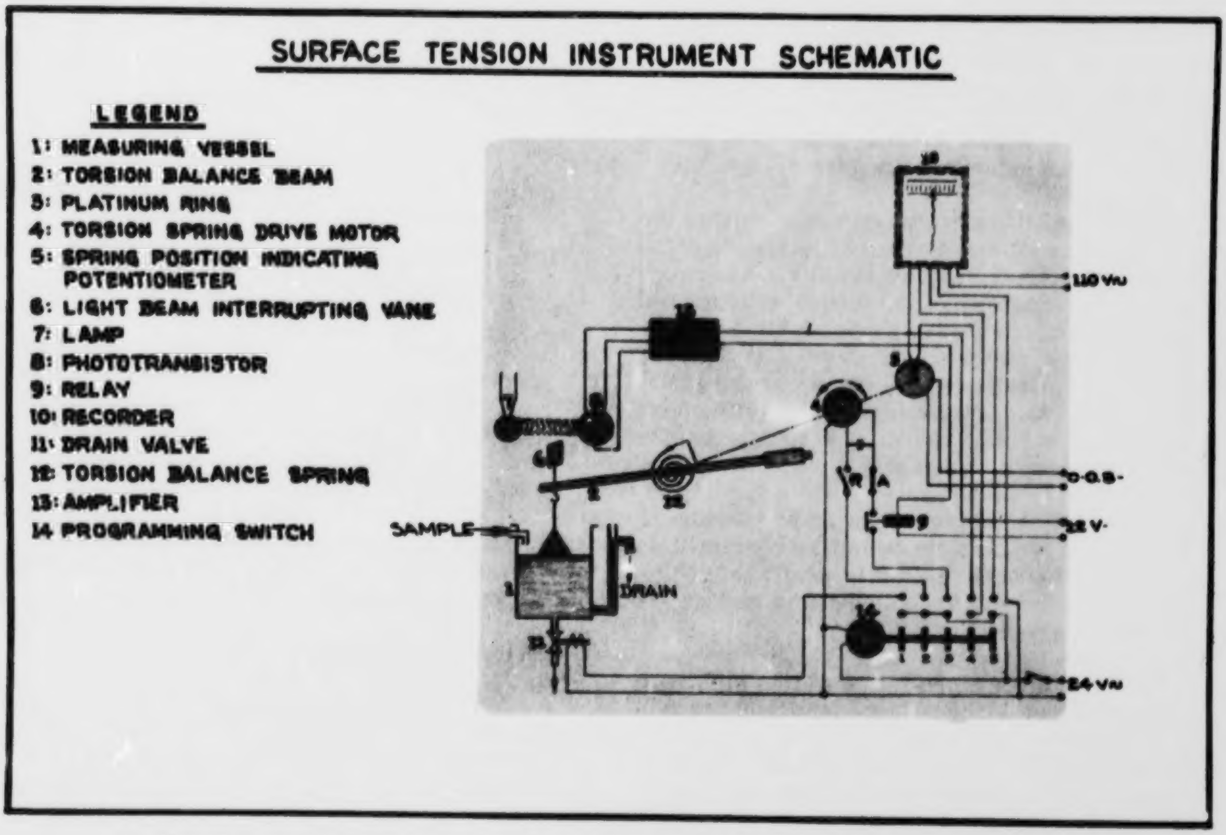

SURFACE TENSION INSTRUMENT SCHEMATIC
LEGEND
1: MEASURING VESSEL
2: TORSION BALANCE BEAM
3: PLATINUM RING
4: TORSION SPRING DRIVE MOTOR
5: SPRING POSITION INDICATING POTENTIOMETER
6: LIGHT BEAM INTERRUPTING VANE
7: LAMP
8: PHOTOTRANSISTOR
9: RELAY
10: RECORDER
11: DRAIN VALVE
12: TORSION BALANCE SPRING
13: AMPLIFIER
14: PROGRAMMING SWITCH
110 V~
D.C.S-
12 V-
SAMPLE
DRAIN
24 V~
1
2
3
4
5

FIGURE 43. SCHEMATIC DIAGRAM OF SURFACE TENSION INSTRUMENT.

The heart of this instrument is an electric torsion balance, the beam of which has located at one end a duNouy type platinum ring for measuring the surface tension of the water, and at the other end an adjustable counterweight. The center pivot of this beam carries a torsion spring, the tension of which is adjusted by means of a motor. In measuring water surface tension by means of the ring method, it is imperative that the lifting force be applied to the ring at a uniform rate. This is accomplished by means of a reversible synchronous motor that winds the torsion spring of the balance at a constant rate. If this rate was not applied uniformly, the duNouy ring would break away prematurely and provide low readings which would be a source of error in an instrument of this type.

After the measuring vessel, 1, has been flushed for approximately three minutes by fresh sample, the platinum duNouy ring is moved downwards and settles on the sample surface by means of the spring tension motor. The timer controlled starting of the synchronous motor, 4, lifts the balanced beam by rotating the torsion spring attached to the balance beam at the center pivot. However, since the platinum duNouy ring still adheres to the liquid surface because of the surface tension of the water, the balance beam remains horizontal. While the motor winds the spring of the torsion balance, a potentiometer, 5, which is coupled with the motor and serving as a transmitter is varied accordingly. At a certain spring tension, the liquid surface breaks open so that the platinum ring is released and instantaneously moves upward. The upward movement of the balance beam swings a vane, 6, which is located directly above the duNouy ring at the end of the beam, interrupting the light beam between the light source and a phototransistor, 8. Interruption of this light beam actuates a relay which immediately stops the balancing motor and the position of the potentiometer is then electrically transmitted to any suitable indicator or recorder which is calibrated in units of surface tension. In this particular instrument, the surface tension is expressed in dynes per centimeter.

After the surface tension has been measured, the balancing motor, 4, is reversed and the spring of the torsion balance is gradually released until the transmitting potentiometer and torsion balance beam is returned to the starting position. In the last step of the measuring cycle, the drain valve, 11, at the bottom of the sample measuring cell is opened permitting the sample to flow to drain.

Figure 44 is a view of this surface tension instrument with the front door open and a strip type recorder. The round plastic vessel on the left hand side of this cabinet is the sample measuring cell to which the water sample flows. The square box in the center top is the torsion balance and projecting from its left hand side can be seen the small lever from which the duNouy surface tension measuring ring is hung. Beneath this square box is another cabinet containing the electrical programmer and amplifier.

Figure 45 is a view of the surface tension measuring instrument removed from its cabinet. In this view the serrated edge of the overflow weir in the surface tension measuring vessel can be clearly seen. This is a very important feature of the instrument, and provides for a very even and constant level of the water surface.

RESIDUAL CHLORINE

The sterilization of water for all purposes today is accomplished almost exclusively by

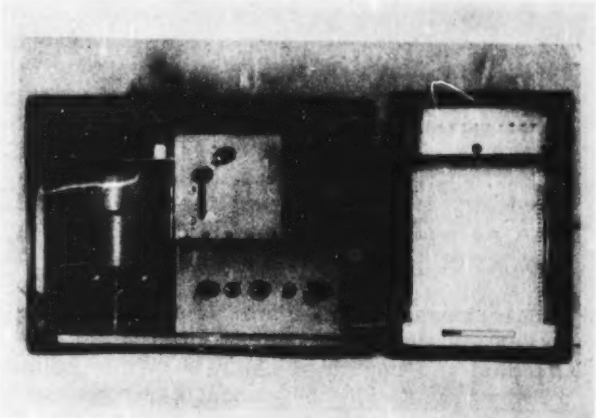


Figure 44. FRONT VIEW OF SURFACE TENSION INSTRUMENT.

Figure 45. SURFACE TENSION INSTRUMENT REMOVED FROM CABINET.

addition of minute quantities of strong oxidizing agents, such as chlorine, chlorine dioxide, ozone and others. In this process the proper dosage is of decisive importance. If too low, the effectiveness of sterilization becomes uncertain; if too high, unpleasant taste and odor as well as corrosion in the pipe lines may result.

The measurement of the residual chlorine content of the water is of two types, free chlorine and combined chlorine. While some water chemists use the amount of free residual chlorine as a measure of the effectiveness of chlorination, health departments of most states are requiring that total chlorine be the measure of the completeness of chlorination. The most popular and practical methods of measuring residual chlorine can be broken down into colorimetric and amperometric or depolarization methods.

Amperometric methods of measuring residual chlorine have been used quite frequently and they have the further advantage that they can be quite readily adapted to the measurement of total residual chlorine which would include both the free chlorine plus the combined chlorine, or it can be used to measure the free chlorine alone. In an amperometric type of instrument, this choice is made simply by the proper selection of the reagents used. Normally potassium iodide is the reagent for total chlorine and a buffer solution is used when measuring free chlorine only.

In the amperometric type residual chlorine analyzers, the water to be tested passes between two electrodes of different metals, one of which is usually a noble metal such as platinum. These electrodes are so selected that the polarization of the electrode of the nobler metal prevents the flow of an electric current in the absence of an oxidizing agent. However, in the presence of even minute traces of sterilizing agent of an oxidizing nature, electric current is generated because the polarizing layer is oxidized by these agents. This reaction is also called depolarization, and the amount of depolarizing current thus generated is proportional to the concentration of the strong oxidizing agents in the water. If a constant potential is maintained across these electrodes, this current will, therefore, be directly proportional to the residual chlorine content and may be indicated by a galvanometer or other current measuring device.

For measuring residual chlorine in Germany, an instrument known as Depolox[9], which is an amperometric type of instrument, has been quite extensively used. Figure 46 is a picture of the Depolox residual chlorine measuring instrument, a modified version of which is now being manufactured in this country by the Fischer and Porter Company[10].

Figure 47 is a view of the measuring cell. Perhaps the most unique feature of the Depolox Analyzer is the arrangement of the amperometric measuring cell. This analyzer cell

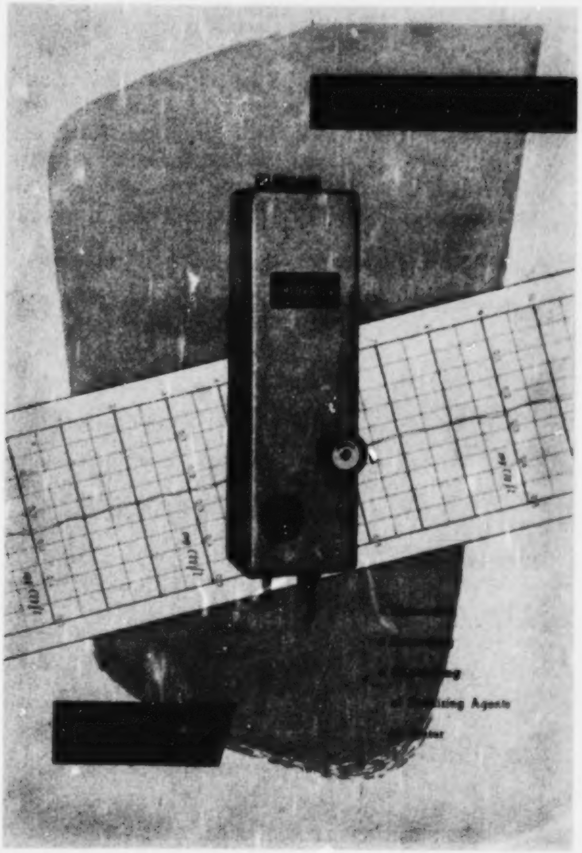


Figure 46. DEPOLOX INSTRUMENT FOR MEASURING RESIDUAL CHLORINE.

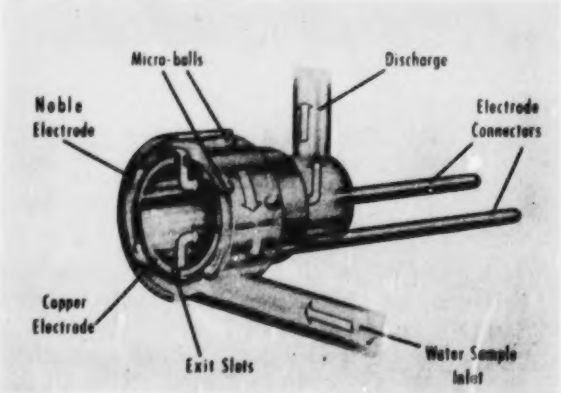


Figure 47. DEPOLOX CHLORINE MEASURING CELL.

consists of two concentric cylindrical electrodes. The outer cylinder being the noble metal electrode, and the inner electrode being the copper electrode. Sample water comes in tengential to the annulus between the two electrodes and rotates at high velocity around the cylinder and then discharges to drain. Also contained in this annulus between the two electrodes is a series of glass balls which are made to continuously rotate by the velocity of the sample water and automatically clean the surfaces of the two electrodes to prevent corrosive build-up or other contaminating materials. Since a constant voltage is maintained across these two electrodes, no current will flow through the cell due to polarization of the noble metal electrode. However, in the presence of an oxidizing compound the polarization layer is oxidized and the current is permitted to flow to the cell which is proportional to the concentration of the oxidizing agent. This instrument normally does not require addition of any reagents when measuring the free residual chlorine except when the pH is above 7.5 it is necessary to add a buffer solution to the sample water.

One of the primary advantages of this amperometric type measurement is that a continuous signal is obtained so that it is possible to control automatically addition of chlorine to the system. Clark[11] of Wallace and Tiernan, in his paper, describes operation experiences of such an instrument which is manufactured by that firm.

Figure 48 is a view of the Wallace and Tiernan residual chlorine recorder and controller which uses an analyzer of the amperometric type[12]. This unit is available complete as a panel mounted unit with a recorder as indicated. This recorder is also available as a control unit for accurately controlling the amount of chlorine added to the water being treated.

This is a very versatile unit and is the first step to complete water treatment automation. With the addition of a set point controller component to the recorder, the unit forms the basis for a complete closed control system for automatic control of chlorination. When used in this manner, this analyzer has been very successful and has resulted in very close control of the total residual chlorine in

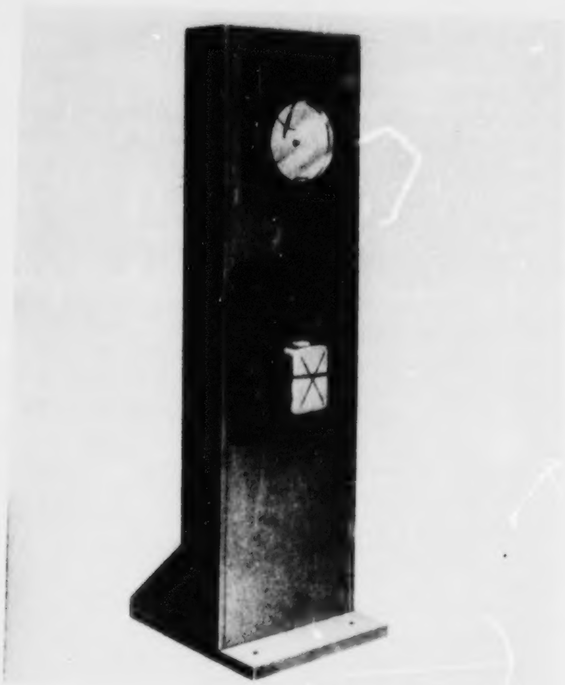


Figure 48. WALLACE AND TIERNAN RESIDUAL CHLORINE ANALYZER AND CONTROLLER.

the water, thereby preventing over chlorination and the subsequent waste of chlorine. Using such an amperometric type instrument it is reported that the minimum amount of detectable chlorine is about 0.01 ppm when working on a full scale range of 1 ppm. The instrument accuracy and reproducability are both approximately plus or minus 2% of full scale on all ranges.

The Foxboro Residual Chlorine Analyzer[13] has been highly successful in the range of 0 to 1 ppm and 0 to 50 ppm of total dissolved chlorine. Figure 49 illustrates this analyzer which is a neatly packaged two piece device consisting of the analyzer and a standard EMF recorder (not shown). The analyzer consists of a specially designed reagent tank on top of which is mounted a sample filter, a reagent proportioning pump, an amperometric measuring cell and a flow controller.

This instrument is quite simple in operation and Figure 50 is a schematic flow diagram of the device. The sample fluid to be analyzed first flows through the filter and then is mixed with a metered quantity of reagent after which it enters the amperometric type measuring cell. After leaving the measuring cell, the sample water which is under pressure is used to power a hydraulic cylinder which actuates the reagent metering pump, and then flows through a flow controller and on to drain.

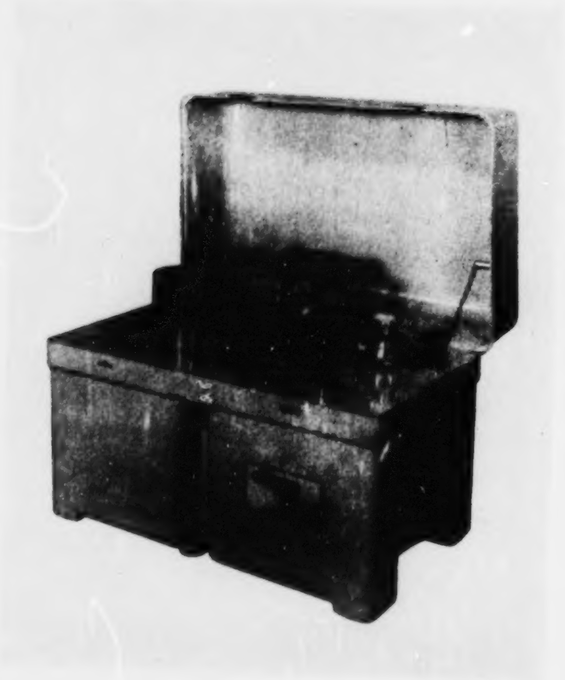
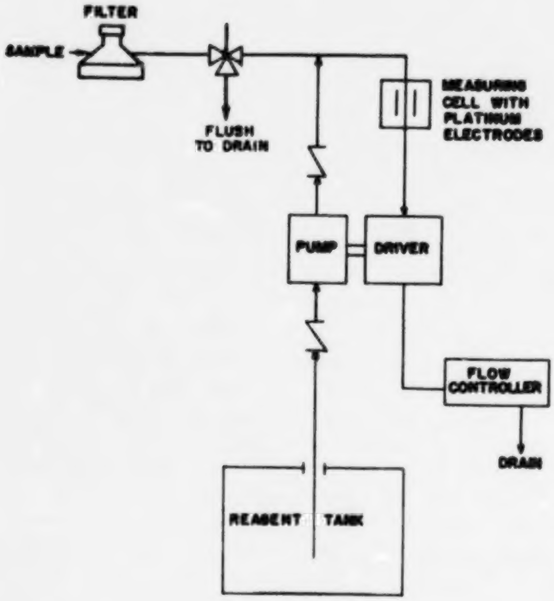


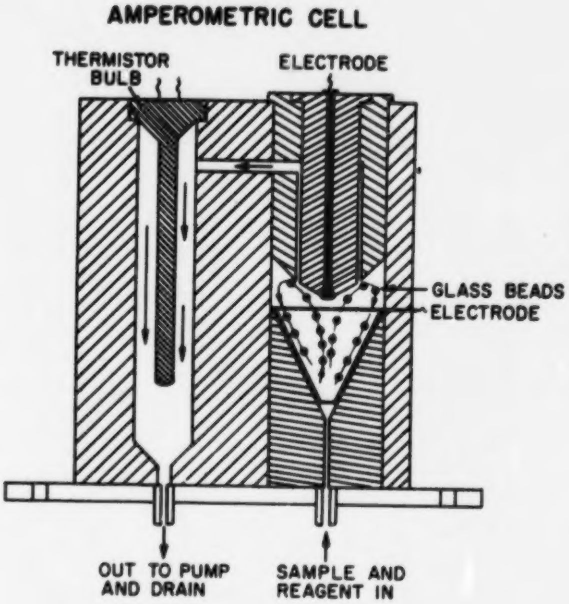
Figure 49. FOXBORO RESIDUAL CHLORINE ANALYZER.

Figure 51 is a view of this amperometric cell showing the general construction details. Sample solution flows upward through the bottom of the cell into a hollow cone shaped copper electrode as indicated. Directly above and mounted in the center of this conical shaped chamber is the platinum electrode. The incoming water velocity agitates a quantity of


FILTER
SAMPLE
FLUSH TO DRAIN
MEASURING CELL WITH PLATINUM ELECTRODES
PUMP
DRIVER
FLOW CONTROLLER
DRAIN
REAGENT TANK

SCHEMATIC FLOW DIAGRAM

Figure 50. SCHEMATIC DIAGRAM OF FOXBORO RESIDUAL CHLORINE ANALYZER.


AMPEROMETRIC CELL
THERMISTOR BULB
ELECTRODE
GLASS BEADS
ELECTRODE
OUT TO PUMP AND DRAIN
SAMPLE AND REAGENT IN

MEASURING CELL

Figure 51. FOXBORO RESIDUAL CHLORINE MEASURING CELL.

glass beads, causing them to impinge upon the electrode surfaces and freeing them of any substance which might adhere. The fluid leaves the measuring cell through the circular annulus around the platinum electrode and passes out over a thermistor bulb and then out of the sample measuring cell.

Temperature compensation is obtained by the thermistor bulb since its resistance varies with the temperature of the sample water. This compensation is very important since current flow through the amperometric measuring cell is a function of water temperature.

Since the most widely used method for measuring residual chlorine by water chemists is the colorimetric method using orthotolidine as the reagent, it is only natural that an automatic analyzer based on this principle should have preference. The orthotolidine method of analysis also has a further advantage in that it measures the total residual chlorine which is in keeping with the requirements of most state health departments.

The Milton Roy Chemalyzer[14] is a fully automatic photocolorimeter which is suitable for measuring residual chlorine concentrations. This unit is a compact self-contained colorimetric analyzer containing a built-in indicator with adjustable alarm contacts. However, it also can be provided with an external recorder to continuously record the concentration of residual chlorine. Figure 52 is a view of one of the early prototype models of this Chemalyzer which was calibrated to measure residual chlorine in the range of 0 to 1 ppm.

The simplicity of this device can be better appreciated by viewing Figure 53 which illustrates the reagent and sample measuring

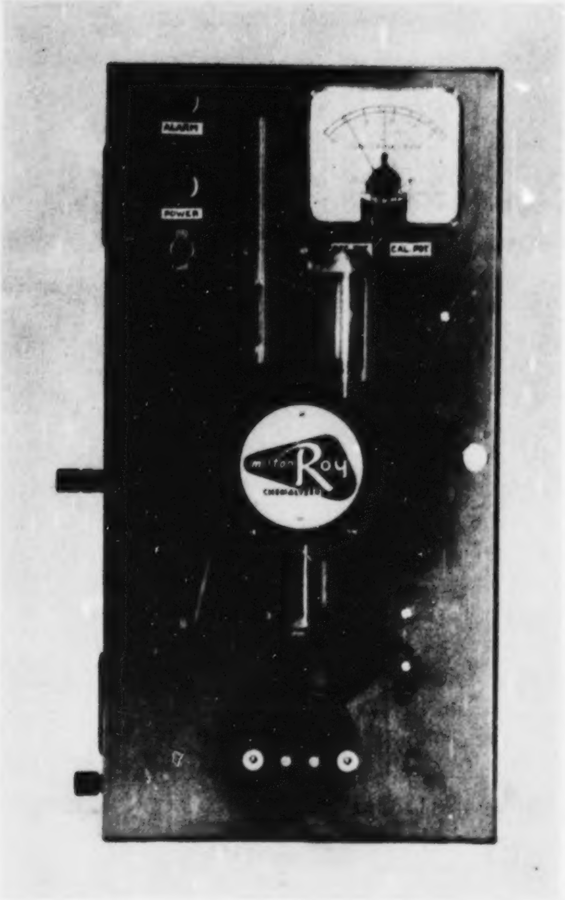


Figure 52. MILTON ROY CHEMALYZER FOR RESIDUAL CHLORINE.

cycle of the Chemalyzer. The working heart and only moving part of the Chemalyzer is a double ported teflon plug valve which is used to accurately meter the quantity of reagent and control the flow of sample fluid to the measuring pipette. In addition to this function, this metering valve also serves as a simple and reliable means of programming the cycle of operation of the instrument. This valve is reciprocated between the two operating positions by means of an indexing motor and cam mechanism. The diagram illustrates the valve in the reagent metering and fluid sampling positions. The sample to be analyzed flows continuously up through a port in the plug valve to the overflow type measuring pipette. This pipette normally has a capacity of 22 ml, but other capacities for various analyses down to a minimum of 8 ml can be installed. This pipette, which is located in the sample measuring cell, overflows continuously to drain during the sampling period, so that complete flushing of the measuring pipette and a representative sample is obtained.

During the sampling period, the reagent flows from the storage container by gravity up through the inclined port (which, for convenience, has been shown horizontal in this Figure) displacing the air trapped in the valve port which escapes up through the reagent sight glass. The volume of air displaced is equal to the volume of the plug port which is 0.7 ml and is, therefore, also the volume of reagent which will be metered by the plug valve port. It can readily be seen that the repetitive accuracy of this arrangement is excellent.

After a period of time, which is controlled by the indexing motor, the measuring cycle is completed and the multi-port teflon plug is rotated ninety degrees until the port is lined up for the drain or mixing cycle. The reagent mixing or reaction cycle now commences with the drainage of the sample fluid from the measuring cell down through the reagent port of the valve plug. In flowing through the reagent port of the plug valve, the fluid flushes the measured quantity (0.7 ml) of reagent down into the reaction or mixing chamber.

Since the ratio of sample fluids to reagents is approximately 30 to 1, it is imperative that the fluids be uniformly mixed before passing on to the colorimeter measuring cell. This mixing action is provided by a series of radial nozzles at the bottom of the mixing chamber inlet pipe. As the fluid flows into the mixing chamber, the agitation produced by these mixing nozzles is sufficient to provide an adequate mixing.

As the reacted sample flows through the colorimeter measuring cell, the ratio of monochromatic light which is transmitted through the sample to that which is transmitted through the standard reference filter is measured by means of two selenium type photocells. Light of the proper wave length for measuring residual chlorine is obtained by using a

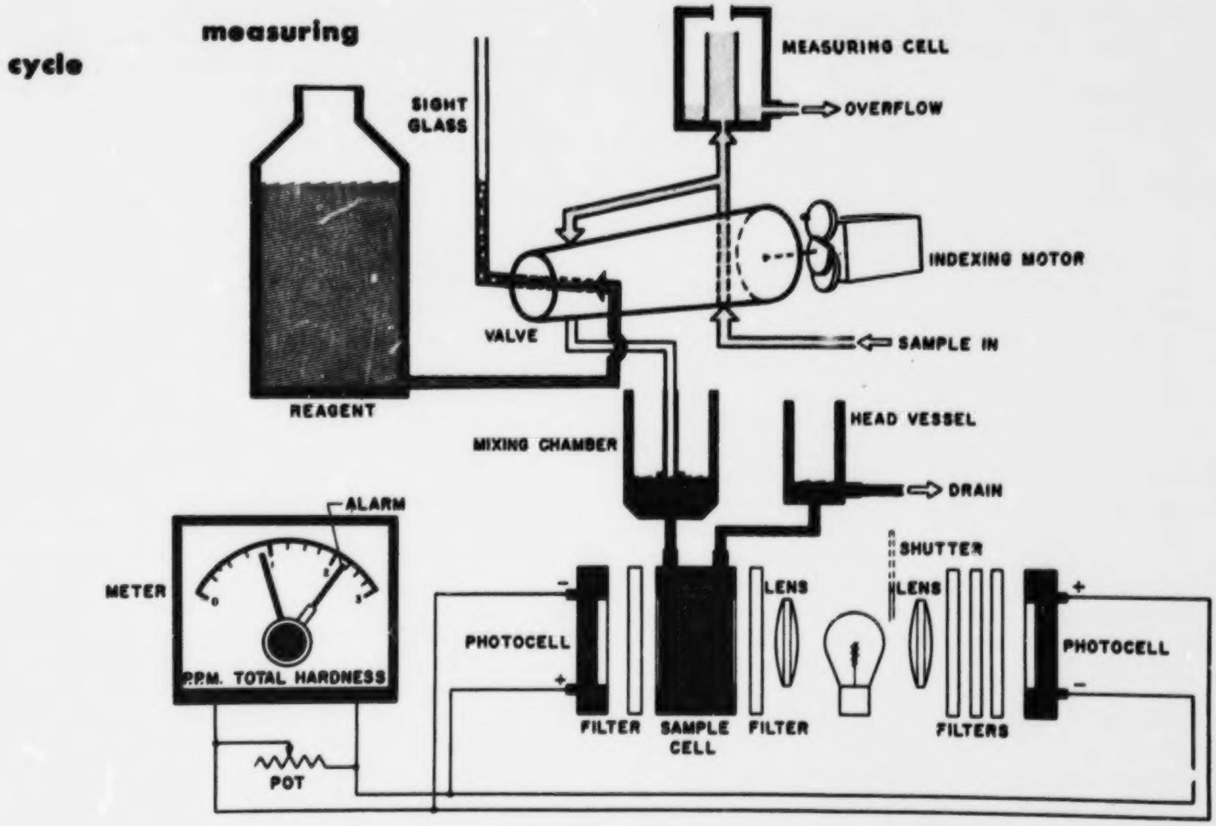

measuring
cycle
SIGHT GLASS
MEASURING CELL
OVERFLOW
INDEXING MOTOR
VALVE
SAMPLE IN
REAGENT
HEAD VESSEL
MIXING CHAMBER
DRAIN
ALARM
METER
0
1
2
3
P.P.M. TOTAL HARDNESS
PHOTOCELL
SHUTTER
LENS
LENS
PHOTOCELL
FILTER
SAMPLE CELL
FILTER
FILTERS
POT
-
+
+
-

Figure 53. SCHEMATIC DIAGRAM OF CHEMALYZER.

Corning No. 5-56 Light Theatre Blue glass filter which peaks at about 450 millimicrons. The two selenium photocells are wired in series so that the difference in output between the two cells is measured by a microameter which is calibrated in terms of parts per million of total residual chlorine. This indicating meter also contains an adjustable alarm indicator which can be set to any value in the range of calibration of the instrument.

TURBIDITY MEASUREMENT

Several companies make photocolorimeters which can be used for the measurement of turbidity of water systems. To mention a few of these, the units made by the General Electric Company and the Beckman Instrument Company are very well suited for this service.

The General Electric Recording Turbidimeter[15] is based on the Tyndall Effect. That is, it measures the ratio of intensity of the scattered light to that which is transmitted through the sample.

The Beckman Flowcolorimeter[16] has been adapted to the measurement of turbidity in water treatment plants. This is a single beam instrument which can be arranged to measure either transmitted or reflected light from the sample. A recording turbidimeter installed in the incoming plant stream is a very useful tool to the plant operator and control chemist. Since coagulation control in a water treatment or waste disposal plant is such a crucial problem, it would be highly desirable if instrumentation could be provided at this point for automatic control. However, turbidity measurements alone do not tell the complete story concerning the physical nature of the suspended solids which are responsible for the turbidity of the water sample.

Buswell[17] in work which he did for the National Institutes of Health proposed a method for coagulation control which appears to be quite promising, and is being presented here for consideration. In his work he found that sedimentation of a sample of raw water could be accelerated by centrifugal force so that coagulation dosages could be determined in a matter of minutes instead of hours as required by making gravity type jar tests. However, in his work he observed that the amount of centrifugal force applied in separating the sample was quite critical. That is, the separating force must be large enough to remove the floc but small enough so that the uncoagulated turbidity will not be detectably removed within the time of application of the separating force. By a series of tests he was able to determine by means of a variable speed centrifuge that a speed resulting in 200 g acceleration provided the desired separation without affecting the turbidity through uncoagulated suspension. By this method, therefore, it appears possible to separate the floc from partially coagulated water without the errors normally resulting from straining or filtering, and thus obtain a sample of the suspension between the floc for turbidity measurement.

Using this method in combination with a turbidimeter, as proposed in his paper "A Method of Automatic Flocculation Control", it appears feasible to automatically control the flocculation operation.

COLORIMETRIC ANALYSIS

Colorimetric methods of analysis have long been a useful tool to the water chemist in the laboratory. Because of the extreme sensitivity, it is only natural that these methods should be the first to become automated for automatic analysis and control of water systems. Dr. Hans Fuhrmann[18] of the firm of Bran & Lübbe of Hamburg, Germany, did considerable work towards the mechanization of such colorimetric principles in 1950. These early instruments of Dr. Fuhrmann were designed primarily to measure the total hardness and residual chlorine content of waters by colorimetric means. As a result of field trials of Dr. Fuhrmann's instruments in this country, Milton Roy Company embarked on a program to develop a similar line of instruments which were built to meet the more rigorous requirements of American industry. As a result of this development program, the Milton Roy Quantichem[19] was developed. This instrument is a fully automatic double-beam photocolorimeter complete with reagent metering pumps which is capable of taking a small sample and accurately measuring the unknown constituents in either the ppm or ppb range. It was only a natural development that this Quantichem would find immediate application in the power industry where very pure waters are required for the modern high pressure boilers. The Quantichem has been successfully used in measuring dissolved oxygen in the 0 to 30 ppb range, dissolved silica in the 0 to 50 ppb range and total hardness in the 0 to 3 ppm range in these boiler plant applications. However, this instrument has been successfully used in measuring total residual chlorine, iron, copper, and other constituents in city water supplies. Work is being done to measure the fluoride concentration of city water supplies and one large steel company is presently experimenting with this instrument to measure the cyanide and phenol concentration in the effluent from its waste disposal system.

Figure 54 is a view of the Quantichem Analyzer which consists of two units, the analyzer on the right and a circular chart recorder on the left.

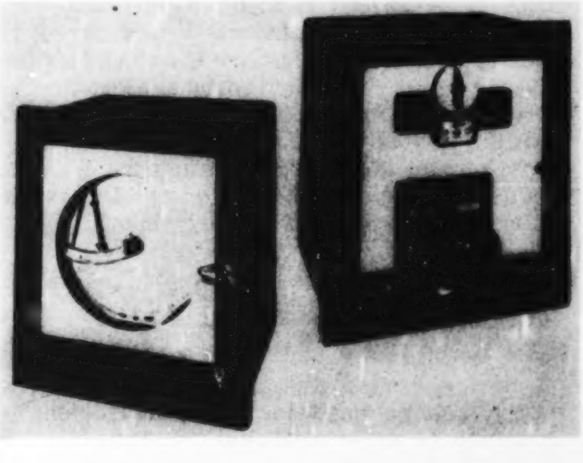


Figure 54. MILTON ROY QUANTICHEM ANALYZER AND RECORDER.

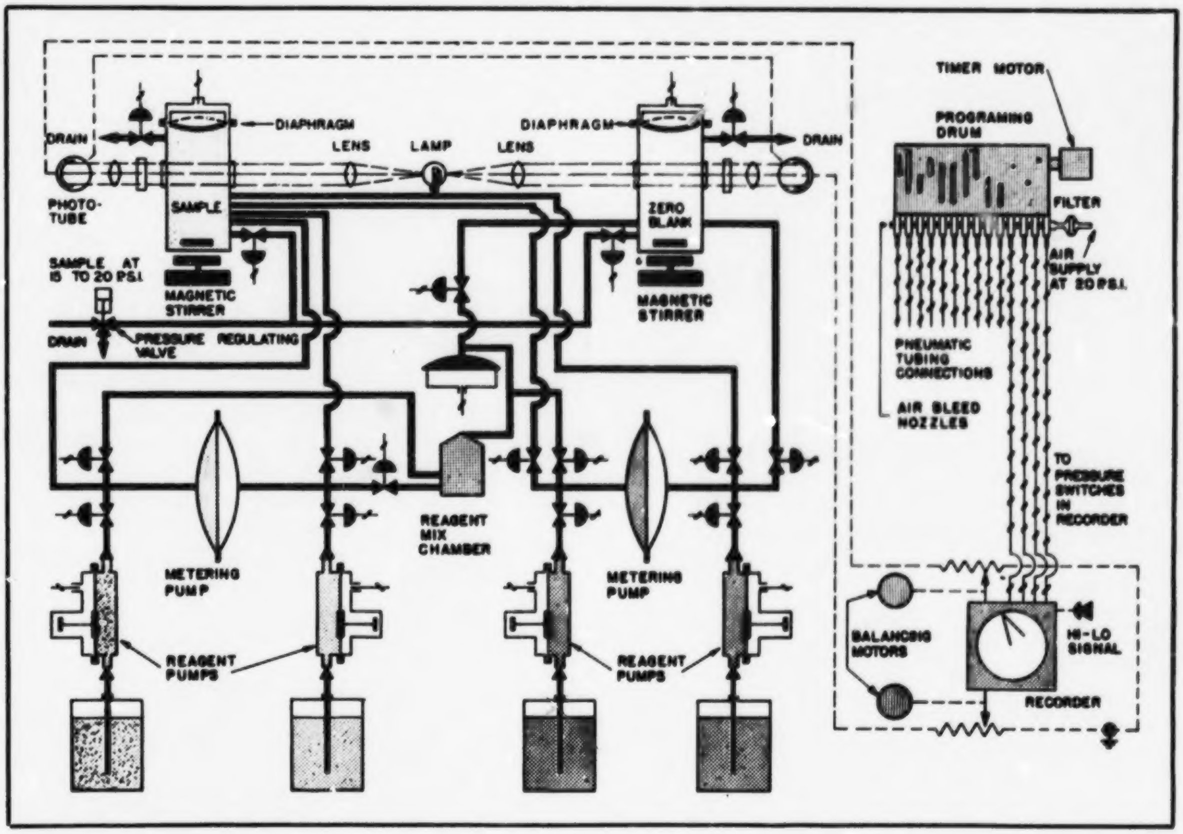

DRAIN
DIAPHRAGM
LENS
LAMP
LENS
DIAPHRAGM
DRAIN
PHOTO-TUBE
SAMPLE
ZERO BLANK
SAMPLE AT 15 TO 20 P.S.I.
MAGNETIC STIRRER
MAGNETIC STIRRER
DRAIN
PRESSURE REGULATING VALVE
REAGENT MIX CHAMBER
METERING PUMP
METERING PUMP
REAGENT PUMPS
REAGENT PUMPS
TIMER MOTOR
PROGRAMING DRUM
FILTER
AIR SUPPLY AT 20 P.S.I.
PNEUMATIC TUBING CONNECTIONS
AIR BLEED NOZZLES
TO PRESSURE SWITCHES IN RECORDER
BALANCING MOTORS
HI-LO SIGNAL
RECORDER

Figure 55. SCHEMATIC DIAGRAM OF QUANTICHEM.

Figure 55 is a schematic flow diagram of the Quantichem Analyzer for an analysis using a four reagent system. The upper portion of this view shows the double-beam photocolorimeter consisting of a sample and a zero blank measuring cell. The reagents are stored in five gallon plastic lined containers and transferred to the instrument by a series of air actuated diaphragm type pumps. The actual quantity of reagent (2ml) is then metered to the sample and zero blank measuring cells by means of a diaphragm type metering device. The complete cycle of operation of this instrument is automatically controlled by a pneumatically programmed system. The program is determined by means of a series of slots and holes in a rotating programming drum which actuates the various pneumatic lines to the valves and pumps.

The Quantichem Analyzer is a very highly precise device which is capable of performing an analysis requiring multiple reagents and is capable of extreme accuracy. However, there are many applications requiring only single reagent or two reagents where the complexity of the Quantichem Analyzer cannot be justified. Therefore, the Milton Roy Company has developed a simpler instrument known as a Chemalyzer[14] for performing such analysis. Figure 56 is a picture of the latest model of this instrument. This analyzer has been previously discussed elsewhere in this paper under the subject of "Residual Chlorine Measurements". However, this analyzer can be adapted to other types of analysis. While this instrument is normally a single reagent instrument, it has also been modified for handling two reagents where required and this latter model can also

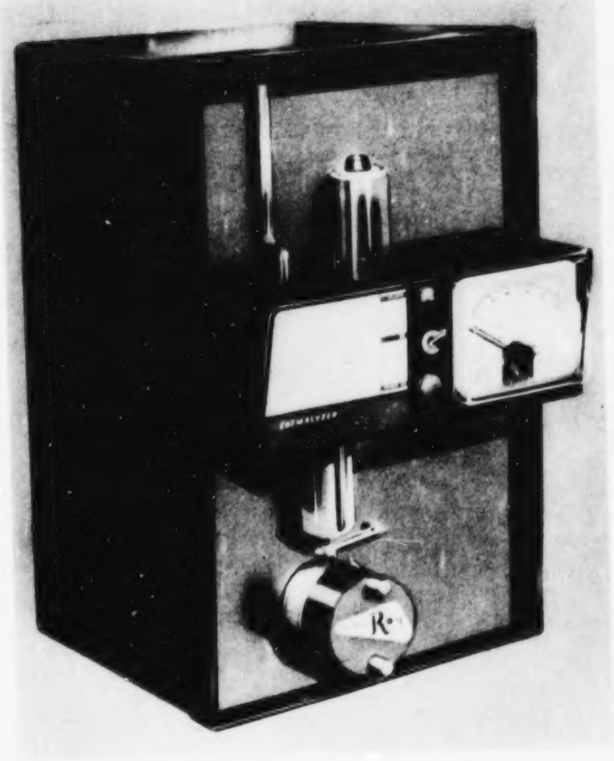


Figure 56. MILTON ROY CHEMALYZER.

be used for performing automatically a 30 to 1 dilution of the sample, thereby, enabling higher ranges of analysis to be performed. For example, using this technique of dilution it is possible to use this analyzer to measure total hardness in the range of 0 to 100 ppm. This instrument should find considerable application in city water supplies where the primary source of water is well water which may contain considerable hardness. Very often in such systems, the hard well water is blended with a source of supply of lower hardness in order to maintain the total hardness within certain limits. For such an application the Chemalyzer could be utilized to advantage to continuously monitor the total hardness of the blended water being sent to the city mains. Figure 57 is a view of a two reagent Chemalyzer which is suitable for automatically diluting the sample.

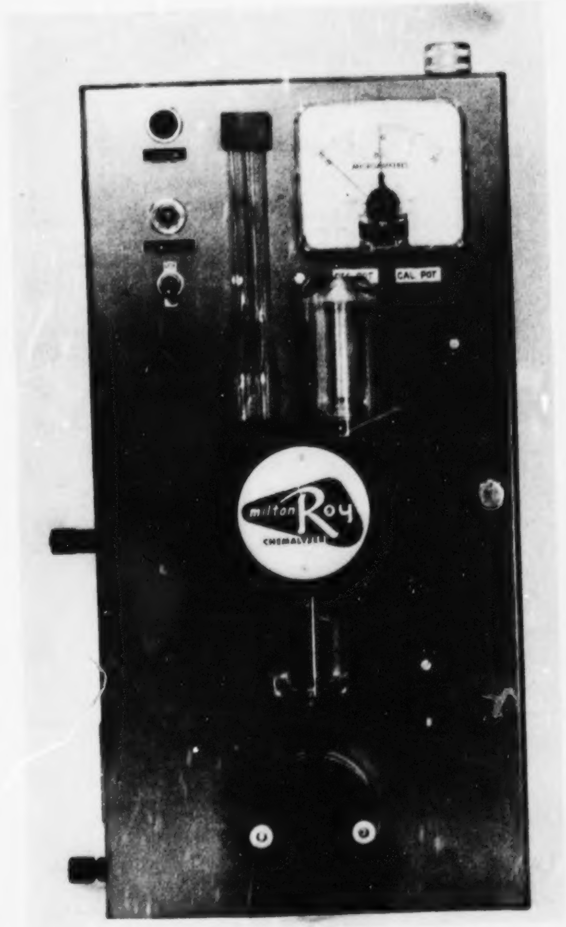


Figure 57. TWO REAGENT CHEMALYZER.

The Beckman Flow Colorimeter which was previously described under turbidimeter, has also been utilized in many city water plants to monitor the color or clarity of the water being sent to the city mains[20].

Hach[21] has also developed a line of automatic photocolorimeters which parallel very closely the work which was done in Germany by Dr. Fuhrmann. These analyzers have been used in the measurement of chlorine, hardness, turibidity and fluorides.

The Technicon Auto Analyzer[22] is a highly automated laboratory type analyzer which has also been used to measure the various constituents in water supplies.

It has been the purpose of this paper to survey the field on work which has been done in recent years to mechanize the important function of water quality control. Rapid progress is being made, and it can be expected that within a few years the reliability of such equipment will develop to the point where fully automated water supply and waste disposal plants will become a reality.

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INSTRUMENTATION (PART I)

DISCUSSION

MR. HUGH A. SCHREIBER (Superintendent Sewage Treatment Plant, Washington, D.C.): We are all interested in instrumentation. However, I fear that those who are developing the systems and those who are coming along with the application at the moment are oversimplifying the problem. The municipality which will ultimately use them, not only will spend many thousands of dollars to buy them, but also will have to service these units, and I think that this servicing phase should be brought out. We have a problem in convincing those who furnish us with personnel and monies to operate, that the type of maintenance personnel required is not the type of instrument technician that was required five years ago. You can't take a plant operator, nor can you take just an electrician and set him alongside one of these $50,000 electronic units and say "take care of it."

The other point that I would like to make is that the instrument manufacturers recognize this, and they have done, I think, a wonderful job of setting up a program on instruction. Certainly we have to go to them for this instruction, but it is, I feel, very valuable to take advantage of any opportunity that any municipality has, to send competent men -- don't send an operator -- to one of these courses. He isn't going to come back and say, "Well it was a push-over."

I would be interested in knowing how long ORSANCO has been developing this unit of automation that will give these seven separate measurements, and how long has this instrument been performing?

MR. EDWARD J. CLEARY (Executive Director and Chief Engineer, Ohio River Valley Water Sanitation Commission, Cincinnati): This is a prototype unit, just completed, and only components have been tested, consequently there is no record of service on the entire unit. But this matter of service has been carefully considered in both the design and construction of the system. This is detailed in our formal paper, which was presented this morning in summary form because of program-time limitation. Now that the question has come up it is appropriate to call our consultant, Mr. Carl Schneider, who designed the instrument to discuss the service and allied matters.

MR. CARL A. SCHNEIDER (Partner, Engineering Specialties, Cincinnati): What we have done in the design of the robot monitor as far as the analysis and transmitting equipment is concerned, is to treat as primary considerations the need for reliability and simplicity of service. This was done with the understanding that this unit will have to be serviced by people who possibly are not competent to do this work if we require of them a complete knowledge of the electronics of the instrumentation.

Each individual analyzer unit is a plug-in module, which can be removed as a unit from the complete analyzer system. As a plug-in module it can be serviced on the spot, or it can be removed for service at a remote point, that is at a central location.

Now to enable a service man who has little electronic background to adjust and calibrate this equipment we have built into the individual analyzers complete self-calibrating systems. By the pressing of a momentary contact switch on the front of each unit, and the flipping of a toggle switch it is possible to check the instruments for zero and full scale calibration. The circuitry in all cases is absolutely stable. There is no long term drift. That is a statement I will make categorically, there is no long term drift. These instruments are accurate within one per cent and will stay that way until they fail completely.

This reduces the service problem then to a periodic check in which a man comes up to the instrument with a screwdriver, opens a small door on the front of each analyzer, presses a button and reads either zero or full scale. After that he flips a toggle switch and reads the other. If an adjustment is required, an adjustment of perhaps one per cent or so on either zero or full scale, he makes this using a control brought out through the front of the instrument. This can be done by almost anyone.

We built these instruments to measure electrical parameters. The electronic instrumentation is isolated from the chemical problem and the electrode problem. The calibration is not dependent upon the transducer, or electrode system, that is providing the signal. In other words, we are providing stable electronic instrumentation with built-in calibration, isolating that entirely from the over-all electrode transducer problem.

In the routine check performed at perhaps one week or ten days or two weeks intervals, there may be some troubles noted from time to time. We plan that the service man will clean the electrode system, will check the calibration of the instruments and then will put them back into operation. If he wishes to run a chemical check against the standard solution, he will have to take the electrode assembly for each particular water parameter and immerse it in an appropriate standard solution. For example, if he is measuring conductivity he would insert the transducer into a solution of known conductivity. If he doesn't read what the standard solution should give him, he may conclude the electrode system is defective. There is no question about the instrument if its electrical calibration has already been checked.

This has been the theory behind the approach we have used on this and we think we can keep the service down to a relatively low cost level since it can be handled by personnel, trained only in the actual calibration operation without the ability to do the detailed servicing.

Now, at each transmitter station in addition to a set of analyzers and a set of flow cells, we have a telemeter transmitter. This telemeter transmitter was designed and built by Minneapolis-Honeywell. They have a nationwide service system and the telemeter transmitter end of this can be serviced on a regular schedule basis by the company.

At the central receiving station, the equipment gets a little more intricate. It includes a Minneapolis-Honeywell telemeter receiver and a Datex Corporation logger. These items do require qualified service, but since they are at the central location it would be possible to have a qualified service man there full time if the size of the operation requires it, to maintain the central station equipment and to repair defective analyzers which are sent in from the field from time to time.

MR. CLEARY: Do you want to mention the test signal device, Carl?

MR. SCHNEIDER: Yes, I should mention that. The reason we can say that the individual units are calibratable by simply pressing a button is that in each instrument we have provided as a test signal the same parameter which the instrument would naturally measure.

For instance, the pH, ORP and dissolved chloride measurements are millivolt measurements. Therefore, we calibrate them with a standard millivolt signal which is supplied in each transmitter station from a constant voltage source; this is an integral part of each transmitter station.

The measurement of dissolved oxygen is primarily a problem of measuring microamperes, so we provide a reference microampere signal for the calibration of that unit measurement, and standard resistors are provided for calibration. And the problem of measuring conductivity and temperature is a resistance. So each instrument is calibrated against standard electrical quantities and you can be assured of the electronic instrument accuracy.

In summary, we have tried to divorce the problem of instrumentation from the problem of detecting. We appreciate that the problem of detecting the signals, using electrode systems and so on, is a great deal more complex. But we feel that you should not be burdened in addition by a problem with electronics. The electronics part can be reduced to an exact science. The electrodes themselves are another matter. How we will develop ways of cleaning the electrodes after prolonged runs, will be determined as soon as this equipment goes into operation; and it is ready to go.

MR. ROBERT H. JONES (Chemical Engineer, Beckman Instruments, Inc. Fullerton, California): I would like to make a brief comment on this problem of maintenance. The instrument manufacturer certainly likes to supply instruments with built-in interchangeable plug-in components, and of course as new instruments are evolved this is not always possible. Instruments evolve -- Henry Ford didn't start out building Lincoln Continentals, he started out with something else. And as we progress the maintenance problem will become less and less.

I know some of us have been accused of living in ivory towers with relatively clean synthetic samples, and we are told to get out of our ivory towers and supply instrumentation that can be plugged in and will run essentially forever without assistance from the operating people.

I feel that this is a gross misrepresentation. We must build a standard instrument; we must build one that takes care of varying samples under varying conditions. For example, pH electrodes will coat where the streams are loaded with carbonates, and this presents a different problem from measuring the pH of sewage where there is sludge and other gunk in the stream.

DR. THEODORE OLSON (School of Public Health, University of Minnesota): Mr. Schneider spoke of stable systems, and some of the photo-receptive devices such as the Clearex cells are subject to fatigue. I believe it is true that the Photo tubes such as the 929, for example, may be subject to some drift during a period of time, and I wondered how he calibrates his apparatus for solar radiation.

MR. CARL SCHNEIDER: We are trying to separate the problem of the stable detecting device from the problem of a stable amplifying system. We treat the amplifier not as an amplifier that is simply putting in a gain, but as an operational device which operates on the signal in some manner to, if necessary, raise the voltage level, but also if necessary, to modify the characteristic, and further if necessary, to introduce temperature compensation. And we can do these things with an operational type amplifier, with accuracy and with stability, and with certainty. We cannot assure that the things which are providing the signals are stable, and I agree with you that this is a problem. We are using solar cells for this measurement with and without ultra violet filters. They are not sure fire things. They will change just as a conductivity cell will get dirty and as other cells will change with age. But we cannot build into the electronic system of an automatic remote analyzer a means for correcting this, since this is a variable for which we don't know the rate of change. The variable that exists at each of the detecting devices is a problem which is still with us and we have no better solution to it than anyone else at present. All we can suggest is that when we make our routine checks if there is reason to suspect the data from a particular analyzer at a particular station, by substitution the service man can put in a new detector unit. If he finds he is getting the same reading then he knows that the one that is in use there is above suspicion at that point.

PROFESSOR OLSON: Do you calibrate them with another type of instrument from time to time?

MR. CARL SCHNEIDER: We maintain an absolute calibration of the electronic instrument. That is, we calibrate initially, and from there on we would compare to the initial calibration. Now in the case of all these millivolt producing devices we are simply reading millivoltage with proper compensation for temperature. But then if the detector itself does change, this requires special attention. I can suggest nothing better for a remote station than substitution of electrodes if there is any reason to suspect those that are in use. I would imagine that after a while we will probably do this as a routine matter, as a check, perhaps every third service call, if routine service calls are made. I shouldn't call them service calls, but calibration calls or checking calls, to clean electrodes and so on, at about two week intervals. Perhaps every six weeks a substitute electrode system for each variable should be substituted to see if the one in use is still satisfactory.

MR. ROY NELSON (I.T. & T. Kellogg, Chicago): What geographical area is contemplated as to the end distance in your 40 station set up?

MR. CLEARY: Fortuitously, Cincinnati is in the center of the river system. It is about

400 miles to the head of the river at Pittsburgh, and 400 miles to the mouth at Cairo. The telegraph line running between those two points can be tapped off at intermediate points.

MR. NELSON: In other words you contemplate 800 miles?

MR. CLEARY: The total mileage will be influenced also by location of stations on the tributaries, and by the design of the signatory states who may wish ultimately to relay data into state capitals.

MR. NELSON: Now I ask Mr. Schneider whether the telemeter system uses a one way system in that the information is transmitted from your various robots to a central point.

MR. SCHNEIDER: Yes.

MR. NELSON: No reverse interrogation?

MR. SCHNEIDER: The individual transmitting stations are interrogated at a regular pre-set time interval as selected on the digital clock in the combination telemeter receiver data logger cabinet. We can start an interrogation of the stations in sequence at half hour or hourly intervals. Stations are interrogated by calling with a three-digit pulse code from a Secode encoder. All stations are connected in series on the line. Only one station has a decoder which is capable of answering a particular coded call. There are forty different coded calls. The station with the decoder which can answer will answer and then begin to transmit data. Data points will come in at the rate of one every six seconds. At the receiving end they are programmed and recorded as they come in.

They are recorded on a recorder, and converted to digital form for recording on a log sheet. On the log sheet they are typed up with station number, day of the year, time of the day, and a test signal from the transmitter. This test signal serves a dual purpose of checking both the transmitter, and the receiver telemeter and logger system. We send the digital number 1-0-1-0 or 1010. We have a total range of zero to 1200 in our logging system, plus multipliers to extend ranges so we can record all data in engineering units on the log sheet. The test signal of about 80 per cent of full scale is sent from each transmitting station. If all the test signals are in line everything is in order. If all of them are off, the receiving station is obviously defective. If signals from one or two stations are off and the others are satisfactory, those transmitting stations are defective. By transmitting test signals we not only check the station but if the test signal to that recorded is reading only 80 per cent of what it should be, we can correct all the erroneous data by simply multiplying it by the ratio of the correct signal and thereby not lose data in case of telemeter partial failure.

The telemetering is by wire; the 15 cycle line is the least expensive leased line available for telemeter purposes. We transmit by furnishing from our analyzers a signal of zero to 50 millivolts to the telemeter. It is then converted to a 5 to 15 cycle variable frequency signal sent out as a series of pulses, each series for a duration of six seconds, when received at the other end, the frequency signal is converted back to a millivolt signal and then transformed to digital form by the decoder and logged on a typewriter and tape punch. Incidentally, we make this tape punch record also so that this data can be run through a computer at regular intervals to determine, maximum, minimum, averages, recurrence of certain levels, and so on.

MR. NELSON: What is the relative cost of each of the stations installed?

MR. SCHNEIDER: That is a difficult question to answer since we have built only a prototype. It is hard to tell what additional stations will cost. They are not very expensive. They certainly will be comparable in price to the combination of individual analyzers of an industrial quality to do the same things. It probably will be in the $5,000 to $7,500 range. This is not given as an accurate price, but is about as close as it can be pinned down now.

DR. JACK E. McKEE: (California Institute of Technology, Pasadena): You have seven analysis robots. How did you select the seven tests to be run? Was it on the basis of the need for the data more than need of other data, or was it on the basis of availability? In other words were these the tests that are capable of being automated.

MR. CLEARY: It was on the basis of both. We took what we could find available, and then we had also need for certain things. For example, we are engaged in a chloride control program. The addition of ORP measurement is primarily related to some contemplated research on the application of this parameter to river-quality assessment.

We have some additional instruments on test and on order. For example, we have placed our order for a new instrument that measures surface tension and we are also testing devices for measuring turbidity.

MR. GEORGE W. SCHNEIDER (Research & Development Department, Milton Roy Co., Philadelphia): The German instrument Mr. Cleary referred to should be delivered shortly. The Germans have done quite a bit of work with it on the Elbe River. We find the instrument is quite sensitive to vibration. However, it is possible to mount it on a very stable platform and get fairly decent results with it.

MR. CLEARY: We are going to place this instrument at a power station for initial tests. When I first saw the instrument in 1954 it was mounted in a rowboat and it seemed to be pretty rugged.

MR. GEORGE SCHNEIDER: I believe that is correct. In Germany the men who are interested in measuring instruments of this type seem to be a little more patient from the service standpoint than we are. During my trips to Germany I have noted in many water plants and chemical factories that it is quite common to send out a Ph.D. every day to check an instrument. In America we have a different philosophy, we don't like to use high priced talent for this purpose. Also, in Germany there has been a lot of emphasis lately, on stream programs. The government has given most manufacturers a big tax deduction if they will install waste treatment systems. It is rather late, I guess, in Germany, because the use of surface streams for domestic water is not as great as it is in the United States. They use it to wash, but their streams are so highly polluted it is dangerous and they must do something. I think that is the reason why our company has found so much activity and so many instruments developed in Germany.

We did not experience good results with earlier instruments brought to this country because of the maintenance problem. Photo cells, for instance, have been mentioned. For single cell instruments photo cells drift badly and run out of calibration. They would calibrate them daily in Germany. Here this is not considered practical.

MR. CARL SCHNEIDER: A thought occurred to me regarding Professor Olson's question. We have done one thing to attempt to eliminate this solar cell drift. We are measuring a ratio of outputs of two cells. We are not measuring an output from a cell and using that as a signal alone, appreciating the fact that this would give us a very serious stability problem in a short time from the detector itself.

MR. SAMUEL BAXTER (Commissioner, City Water Dept., Philadelphia): These are two unrelated questions to Mr. Cleary. First, where do you intend to place these instruments in your 40 stations or more? Are you going to do any cross-sectioning of the river by samples? Second, how much are the leased lines going to cost annually for the telemeter service, and have you thought of micro-waving the information up and down the river?

MR. CLEARY: We are working on a mobile monitor to be mounted on our river-surveillance boat. We expect to use this monitor for traversing and cross-sectioning river conditions. Another thought in that connection has been the development of a monitor in a buoy with a radio sending device. It would be a simple matter to shift these buoys in the river and thus determine the best location for sampling.

Now with regard to cost. The least expensive of the line services is 75 cents per month per mile. Intermediate taps can be made of a small additional charge.

COMMISSIONER BAXTER: I presume the telephone lines were cheaper than microwave.

MR. CLEARY: Yes.

MR. RICHARD O. JONES (Biologist, Fish and Wildlife Service, Marion, Alabama): We recently acquired an oxygen analyzer of the type Mr. Schneider described with the silver anode and platinum cathode electrodes surrounded by a membrane and electrolyte. We found when we checked this with an ammeter that when we first placed the electrodes (with the membrane) into the electrolyte we got an initial surge on the ammeter, after which it subsided and remained stabilized regardless of the oxygen transmitted. On the surface it appears it might be that the supply of oxygen which was in the electrolyte was instantly exhausted and we were not getting oxygen atoms through the membrane. What are the characteristics of these membranes and where may desirable membranes be obtained?

MR. GEORGE SCHNEIDER: I don't think the trouble is in the membrane. It sounds like other troubles in the electrode system. We have done a lot of experimenting with membranes, and the best plastic for this purpose seems to be polyethylene and the Teflons. Sometimes the Teflons will become coated on the outside if they are in waters which contain materials which have this property. The membrane must be replaced quite frequently in these applications. Is your voltage correct on the cell?

MR. JONES: We checked the ammeter, the trouble is not there.

MR. GEORGE SCHNEIDER: Have you checked the electrode?

MR. JONES: We checked the electrode with a similar one which was made in our own laboratory, but we got the same results.

MR. GEORGE SCHNEIDER: It sounds like it is a voltage problem. What voltage are you carrying, about 1.1 in the cell?

MR. JONES: I am not sure of the exact figure on the voltage.

MR. RUSSELL H. BABCOCK (Manager of Water and Waste Division, The Foxboro Company, Foxboro, Mass.): I don't want to believe it is the polyethylene. I had an opportunity to visit Dr. Kanwisher in his laboratory and he uses two sources of polyethylene: One is the bags that his shirts come back from the laundry in, and the other is one that his wife carries carrots home from the chain store in. He prefers the one that the carrots come in. Actually you can use the cheapest, most readily available form of polyethylene.

MR. WILLIAM L. KLEIN (Chemist-Biologist, Ohio River Valley Water Sanitation Commission, Cincinnati): I have been asked a number of times by people who have had trouble with these electrodes, "why they don't work." One reason we have found is the lack of velocity past the electrode, and therefore no response. The signal tapers off to a stable condition.

MR. JONES: We did check the velocity, sir.

MR. FRANK E. WING, JR. (Manager, Special Products, Jarrell-Ash Company, Newtonville, Mass.): I think the problem you have with the electrode is one that is a little more involved than can be handled in the discussion here. I don't think it is in the electrode itself, but rather in the temperature compensation and amplifying system. Possibly the current across the electrode itself.

MR. ALVIN R. MORRIS (Research Assistant, Lehigh University, Bethlehem, Pa.): I have a number of questions for Mr. Cleary, et al. First, I wonder if any of the other people have found their electrodes to be photo sensitive?

MR. KLEIN: We have found the electrode is photo sensitive although it isn't a problem to us since our electrode is mounted in a flow cell.

MR. MORRIS: That corroborates our information. We have our cells encased in brass "pants" as we call it, but it is just hidden away from the light. We found it made at least two and a half to 5 per cent difference in our readings.

Why don't you record turbidity? What is the duration of standardization of the oxygen electrode? How long can it go without being recalibrated? And finally, do you have any idea what the man hours involved in checking the transducer will be? This need not apply to the amplifier. We will assume it is working correctly as you made provisions for it. But what about the transducers? They are the important part of the system and what they detect is going to be amplified and come out as the answer to the determinations.

MR. CARL SCHNEIDER: We haven't done anything with turbidity as far as the robot unit is concerned although ORSANCO has been recording turbidity for some time. The main reason we have done nothing with turbidity is that we haven't developed a way to package the thing small enough to be consistent with the size of the other units. It is a desirable measurement but this is something for the future.

We have found the electrode to be satisfactory over a period of about a week. Whether it will make a two week period or not, we don't know yet. We certainly do intend that the oxygen electrode will get a new membrane and a new electrolyte solution at each regular service call, whether this is every week or every ten days or two weeks.

In regard to the man hours required for electrode servicing I would say that the routine service calls will result in a use of about one to two, man hours per week. If a service man was operating out of one point, circulating continuously to cover the forty stations, possibly even including his traveling time, I believe he could do this on a two week cycle. It is our intention that the electrode be cleaned every two weeks, that they be checked at some regular intervals, perhaps every six weeks, and that the service man will simply replace questionable electrodes and take them back to Cincinnati. If this is service provided on a unit by someone at a waterworks, then of course he may do the checking and try to decide what to do about the electrode afterwards. But it will be necessary to have substitute sets of electrodes. There is no other satisfactory way of doing this, and that is a relatively trivial cost in the overall picture, compared to the time that would be thrown away by guessing whether or not the electrodes are all right.

MR. MORRIS: Have you found that you can interchange oxygen electrodes without restandardization and recalibration?

MR. CARL SCHNEIDER: Since we only have one we have no way to find this out. We have a Jarrell-Ash epoxy cast unit. It is my understanding that it was one of the very first made, and we have had it for several months. We have had good results, although it is a very difficult thing to say whether or not we have completely satisfactory calibrated performance from it. Let us say that it is consistent with what we would expect. Since we have no second one we can't compare them. We will, before we are through.

MR. MORRIS: Temperature compensation has been one of our bugaboos, using electrodes. Do you use the compensation built into the electrode by Jarrell-Ash?

MR. CARL SCHNEIDER: We do not. The thermistor in the electrode has too low a resistance for our analyzers. We put in an auxiliary thermistor probe which provides much higher resistance, and we introduce our compensation in our operational amplifier in such a manner that we get a multiplication of the temperature compensation effect of the thermistor alone. In so doing we have been able to over compensate, something which apparently was a big problem earlier. That is everyone felt that the thermistor was not available which would give adequate compensation without cascading of resistors, with resultant great loss of signal level. We are simply putting it into the amplifier loop in such a manner that we get a multiplication of its effect and it has worked very satisfactorily.

MR. WING: There was a comment about the polyethylene or Teflon, which is used as a membrane for the Kanwisher-Carritt electrode. We have found that the polyethylene that one gets from the laundry has been fairly good.

However, it is not uniform in thickness. We prefer a 5 mil thick polyethylene membrane. We find that the available Teflon is in the order of one, rather than 10 mils in thickness. This also varies. We are now attempting to obtain a uniform polyethylene from the manufacturers.

The diffusion current of the oxygen through the Teflon is more rapid than through the polyethylene, so it becomes necessary in that case to add physical resistance. For example, we can use Kleenex over the cathode, in the KOH solution. You must bear in mind that we have only sent out twenty instruments initially. These instruments are in the hands of most competent people. On our part we would like to see these instruments tried for a longer period of time. We already have had suggestions on changing the design of the electrode itself. For example, the epoxy resin which we have used now seems to develop a labyrinth of holes until it reaches a spongelike consistency. This doesn't add anything to the performance of the electrode.

We have changed this material; we have reduced the mass of the electrode, and increased the surface area by the addition of veins.

We also are making an attempt to counteract the effects of diffusion of current across the surface of the membrane. This, indeed, is a problem. We were advised originally that an optimum flow rate would be approximately zero point one centimeters per minute across the surface of the membrane. This we now find is not true.

We are contemplating the installation of a small propeller, actually, at the surface or the tip of the electrode, to give a constant velocity across the surface, and therefore a constant diffusion current.

There are other changes that we are making, such as completely rewriting the instruction manuals. This has been pointed out quite clearly as being badly needed.

POLLUTION CONTROL BY CONTINUOUS DISSOLVED OXYGEN ANALYSIS AND ASSOCIATED INSTRUMENTS

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Analytical Instrumentation
The Hays Corporation

As an engineer working for an instrument manufacturing company, it is a rare privilege for me to be able to address a group as vitally concerned with the problem of sanitation, sewage disposal and stream pollution, as this group obviously is. Before starting this paper, I had to ask the question, "How have we in the United States been doing in more recent years with regard to our sewage disposal problem?" As a partial answer, in 1945 there were 5,580 sewage treatment plants in the United States. In 1957, there were 7,518 sewage disposal plants. This represents an increase of about 30%. In spite of this increase, it has been estimated that we are unable to keep pace with the pollution problem. If we are not keeping pace currently, certainly we cannot expect to keep pace by the year 1970, unless a very active pollution control program is adopted. Our three hundred billion gallons per day water bill will certainly not diminish with our increasing population and industrial load. Experts are now predicting that water consumption will jump to 450 billion gallons per day by 1975, or almost 40% of the 1,164 billion gallons per day run-off. It has been further estimated that consumption will jump to 600 billion gallons per day by 1980.

In order to step up a program of control for the future, it has been necessary to incorporate analytical instrumentation into the program of analysis. With the advent of instrumentation into the control field, a growing demand has arisen for continuous monitoring analytical instruments for pollution control. This paper describes the development of a continuous dissolved oxygen analyzer for surface water and discusses other associated analytical instrumentation which is necessary to provide a true picture of stream, disposal pond, and sanitary district water purity.

The dissolved oxygen analyzer discussion covers the principal of operation of the analyzer and some of the unique applications we have encountered. The analyzer utilizes a rather unique combination of Henry's Law and the paramagnetic properties of oxygen to provide an analyzer which is independent of temperature, pressure, solids content, or salinity.

I will also try to describe how other analytical instrumentation associated with the need for dissolved oxygen is important in stream hydrology and how all of these variables can be recorded in one unique recording system.

The United States Public Health Service started an active program in the middle '50s to develop a surface water dissolved oxygen analyzer. The theory and first pilot model of this instrument were developed and Hays was asked to build a prototype industrial type unit which could be taken outside the laboratory. According to the request, the instrument should be able to work successfully in turbid waters with up to 2,000 milligrams per liter of suspended matter. It should have a range of 150% saturation with a maximum error of 5% of saturation. The time constant of this instrument was specified to be not greater than 20 minutes. In addition, the instrument was to be shock and corrosion resistant and should be portable, having no component weighing more than 100 pounds.

This instrument was developed by my company and we have exceeded this contract specification as follows: the instrument has operated successfully upon turbid waters containing 10,000 milligrams per liter of suspended matter with a maximum error of 2-1/2% and an average error of 1-1/2% saturation. The time constant is 2 to 3 minutes. The basic analyzer has withstood the Navy shock test and all components are rugged and corrosion resistant. The complete system is not yet portable, but the component parts do follow the specifications and no one piece cannot be carried by hand.

In order that you may better understand the need for dissolved oxygen analyzer, I would like to review a few facts. You should be aware of the hydrologic cycle, a name applied to the natural process of water recirculating from the land and sea to the clouds and back to the land and sea. The average annual rainfall in the United States is approximately 30 inches. Of this 30 inches, 72% is lost by evaporation, leaving about 8-1/2 inches per year to replenish the ground water; to recharge the rivers, lakes, rivers and underground stores; to provide for stream runoff; and to be used by cities, industries and farmers and for recreation. While the rainfall may be light or heavy from year to year, the fact remains that the average annual supply is approximately 30 inches and this quantity remains constant. This has a great bearing on the pollution problem and makes it necessary that we use our water resources to our best advantage.

It is quite natural that our streams and rivers should be used as a means of disposing of the waste by-products of our cities and industries. They provide a natural and logical disposal method. Each stream has a natural assimilation capacity of waste products; however, if we overtax the stream's natural assimilation capacity, we will degrade or pollute the river. In order to prevent polluting our surface water, we must use a combination of the natural sewage assimilation capacity of the streams and other artificial means to prevent overtaxing the stream's capacity. Pollution control is therefore, a key to the reuse of surface waters.

I would like to call your attention to Table 10 in order to further magnify the problem that faces us with regard to pollution control. Please remember, when we review these figures, that the annual rainfall is approximately 30 inches and has been, and will be, constant each year. This table is a comparison between conditions in 1860 and the conditions in 1960. Note that U.S. population in 1860 was about 31 million. Today, it exceeds 175 million. This is an increase of over five times. 100 years ago the number of communities served by sewers was 10. Today, we have over 11,200 communities served by sewers. This represents an increase of over 1,000 times. In 1860, approximately one million people were served by sewers; in 1960, 57% of the population is served. This represents an increase of 70 times. When you relate these to the fact that we tend to have a constant supply of water to provide for domestic and industrial needs, to provide the irrigation and recreation needs, and to provide us

Table 10. SEWER SERVICES 1860 - 1960.

Comparison	1860	1960	Increase
U. S. population	31.5 M	>175 M	> 5 x
No. communities served by sewers	10	over 11,200	>1000 x
Population served by sewers	1 million	>100 million	>100 x
% Population served	3.2	57	>17 x
	1900	1935-39	1960
Industrial index	< 50	100 base	Nearly 300
	1945	1957	Increase
Sewage treatment plants	5590	7518	30%

1960 Water consumption > 300 Billion gal/day

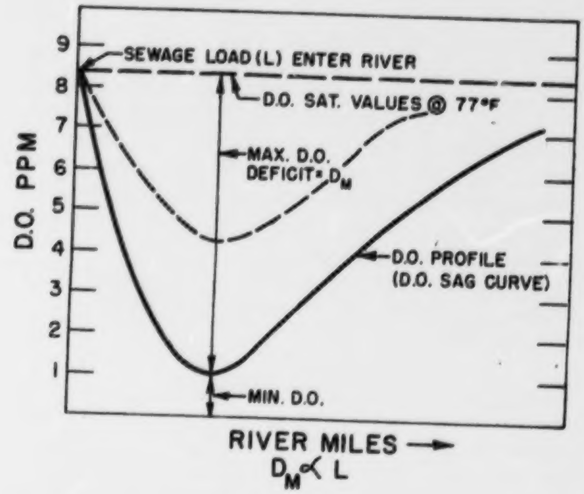

Figure 58. DISSOLVED OXYGEN PROFILE OF A POLLUTED STREAM.

with methods of disposing of our waste, it becomes quite apparent that the pollution control problem is one which can not be ignored. To amplify this last statement, let us look at the population forecast for the United States for the next few years. In 1960, it has been forecast that we will have 180 million people in the United States. It is expected that by 1965, there will be 195 million people in the United States. By 1970, 200 million people are expected to live here. This is an expected increase in United States population of 21 million people within the decade to further tax our water resources.

How does this relate to this discussion? I said I was going to talk about a dissolved oxygen analyzer. In order to understand the interest in dissolved oxygen in surface water, let us look at Figure 58. This illustrates the dissolved oxygen profile of a polluted stream. Let us assume that at point "A" on a river, we discharge a large sewage load (L) into the river. This sewage contains a large amount of organic matter. If the river at the point of entry was saturated with oxygen at a temperature of about 77°F., the water would contain about 8-1/2 ppm of dissolved oxygen. The unoxidized organic material in the sewage load would react and consume the oxygen in the stream, causing a dissolved oxygen deficit down stream from the point of sewage introduction. If this load is great enough, it is quite possible that the dissolved oxygen in the river would be reduced to zero. You will note that the dissolved oxygen profile rises toward the saturated value further down stream. If the river's natural assimilation capacity is not seriously overtaxed, the dissolved oxygen content will return to normal at a point further down stream. The DO profile curve is also referred to as a DO sag curve. The significance of this diminished dissolved oxygen is that oxygen concentrations of less than approximately 3 ppm may not sustain fish and other marine life. As a dissolved oxygen content of the stream approaches zero a point is soon reached at which no fish or marine life can live in the stream. If the maximum DO deficiency is isolated to a short distance in the stream, the problem might be discounted; however, since numerous cities and industries may use this stream to dispose of waste, it becomes apparent the sag curve can be repeated many times in a single stream. If the waste load on the river is sufficiently great, it is quite possible that there will be a maximum dissolved oxygen deficit at all times which will be below the critical value for sustaining marine life. When this happens, the resulting seriously polluted stream becomes a dead conduit of waste material which harbors disease and pestilence. This then, describes our interest in dissolved oxygen for surface water.

The Hay's dissolved oxygen analyzer for surface water is based upon a unique application of Henry's Law. Henry's Law states that at equilibrium, the amount of gas dissolved in a liquid is directly proportional to the pressure the gas exerts on the liquid surface.

At equilibrium

Amount of gas dissolved in a liquid α Pressure "that" gas exerts on the liquid surface

Air is 20.8% O_2 and 79.2% N_2

Let total pressure, $P_{air} = 760$ mm Hg

O_2 partial press. $= .208\ P_{air} = P_{O_2}$

$P_{O_2} = 158$ mm Hg

N_2 partial press. $= .792\ P_{air} = P_{N_2}$

$P_{N_2} = 602$ mm Hg

$$P = P_1 + P_2 + P_3 + \ldots P_N$$

In order to illustrate the use of Henry's Law, as it applies to the Hay's dissolved oxygen analyzer, let us consider that air is 20.8% oxygen and 79.2% nitrogen; also, assume that the total pressure of air is 760 millimeters of mercury of pressure. The oxygen partial pressure is equal to the mole fraction of oxygen times the total pressure of the air, and in this example, is equal to 158 millimeters of mercury.

If we look at Figure 59, we can then apply Henry's Law for oxygen. Here we see that the amount of dissolved oxygen N_{O_2} is equal to $K_{O_2}\ P_{O_2}$, where K_{O_2} is a constant and P_{O_2} is the partial pressure of the oxygen in the system. Looking at the graph below, dissolved oxygen at equilibium of 20°C. is plotted first as a partial pressure of oxygen in millimeters of mercury, resulting in a straight line.

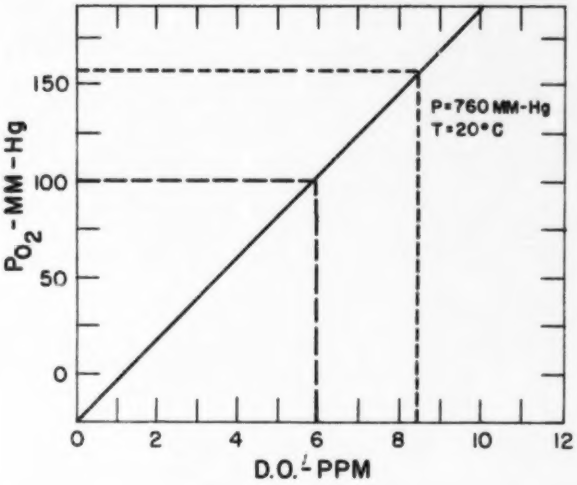

Figure 59. HENRY'S LAW FOR OXYGEN. $N_{O_2} = K_{O_2}\ P_{O_2}$ where N_{O_2}=D.O., K_{O_2}=constant, P_{O_2}=partial press. of O_2.

Note: At 158 millimeters of oxygen, the partial pressure, 8.4 ppm of oxygen is dissolved in water. Note also, that a partial pressure of 100 mm of mercury partial pressure, the dissolved oxygen content is approximately 6 ppm and at 200 mm of mercury, the dissolved oxygen is equal to 11.7 ppm.

Consider a container full of water free of dissolved oxygen exposed to the air in a large room. Assume the temperature is 20°C. and that the pressure of the air in the room is one atmosphere. The partial pressure of oxygen, under these conditions is 158 millimeters of mercury. From the graph just illustrated, the water should contain 8.4 ppm dissolved oxygen. Since the beaker of water contains no oxygen, oxygen will dissolve in the water and at a later time, the water will reach the equilibrium value of 8.4 ppm DO. It is important to note that while there is a significant change in the oxygen concentration of the water, the oxygen in the air in a large room does not change.

A second version takes us one step closer to the final illustration of how the dissolved oxygen analyzer works. A container has air trapped in it at 760 mm of mercury at a temperature of 20°C. Entrapped air is exposed to a large pool of oxygen-deficient water. The initial oxygen partial pressure in the gas phase is equal to 158 mm of mercury as previously shown. Assume that the dissolved oxygen content of the water is 6 ppm, corresponding to an oxygen equilibrium partial pressure of 100 mm of mercury. Under these conditions, the 58 mm of mercury difference between actual oxygen partial pressure and equilibrium partial pressure, causes oxygen to diffuse into the water and, at a later time, equilibrium will be reached. Since the quantity of entrapped air is small, relative to the large pool of oxygen-deficient water, the condition is now reversed from the one previous. In this case, the dissolved oxygen content of the water will remain relatively constant and, in order to reach equilibrium, the oxygen partial pressure in the gas phase must be reduced to 100 mm of mercury. At equilibrium condition, the oxygen in the gas phase is equal to 14.2% oxygen. It can be seen that the dissolved oxygen in the water at equilibrium can be determined if either the oxygen partial pressure or the percent by volume of the oxygen is known.

How does all this apply to the dissolved oxygen analyzer? How can the oxygen partial pressure be measured? The Hay's Magnotherm Oxygen Gas Analyzer (Figure 60) has been used for several years to measure volume percent oxygen in gas trains. Normally, in a gas system, the volume percent oxygen is of interest, but in this case, the partial pressure is desired. A simple modification in the analyzer provides an instrument for measuring oxygen partial pressure.

The Magnotherm consists of a cell which contains two identical heated resistance elements (Figure 61). One of these elements is in a strong magnetic field. Oxygen is almost unique among gases in that it is attracted into

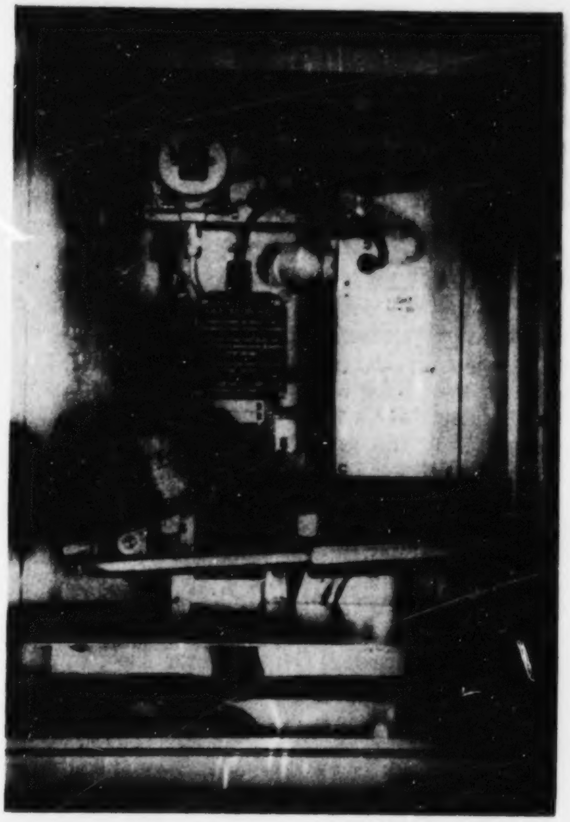

Figure 60. HAY'S MAGNOTHERM OXYGEN GAS ANALYZER.

Figure 61. MAGNOTHERM CELL.

a magnetic field, whereas practically all other gases are slightly repelled from magnetic fields. This property of oxygen is called paramagnetism. Oxygen is attracted by the magnetic field to the vicinity of the measuring resistance elements where, upon being heated, it loses its magnetic property and cooler oxygen molecules are attracted into the magnetic field to take the place of those which have been heated. This results in a recirculation of gas in the vicinity of the measuring spiral which is proportional to the number of oxygen molecules in the vicinity of the spiral. The amount of cooling created by this recirculation can be used as a basis to measure the concentration of the oxygen.

How do we get a gas sample that is equivalent to the D.O. content of the water? Figure 62 shows a schematic diagram of the Hays Dissolved Oxygen Analyzer. The total system consists of a water pumping unit, a contact sampler, Magnotherm gas analyzer, and a Universal Recorder. Water from the pump is delivered at about 50 lb. pressure to the nozzle of the aspirator. It passes through the recovery section of the aspirator into the water-gas separator where it enters tangentially, creating a cyclonic action. A volume of about 100 milliliters gas is trapped in the body of the water-gas separator and the lines running to and from the oxygen analyzer. The pumping action of the aspirator causes this volume of gas to recirculate at a rate of about 2 times per second through the trapped gas system. The gas, upon entering the aspirator, mixes intimately in the recovery section of the aspirator with the incoming jet of water. Since it is recirculating at a high rate it makes excellent contact with the water and quickly reaches equilibrium with the water phase. The water-gas mixture passes from the aspirator to the water-gas separator, where the cyclonic action causes the water to separate from the sample due to the density difference. The sample gas re-circulates through the sample lines to the analyzer, to the aspirator, and back to the water-gas separator. The separated water discharges continuously out the bottom of the water-gas separator to the drain.

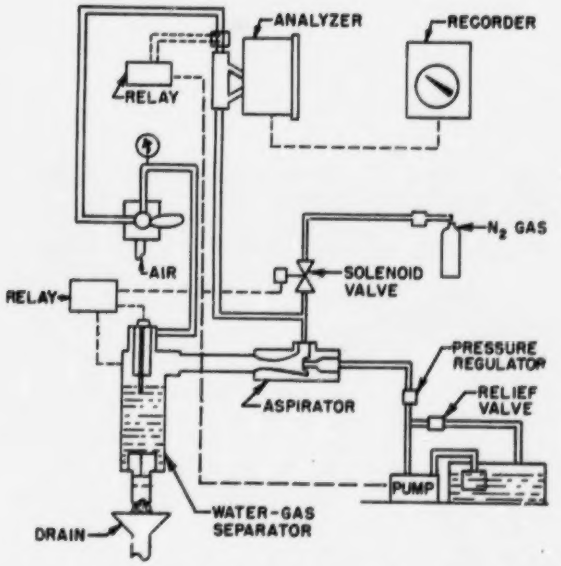

Figure 62. SCHEMATIC DIAGRAM OF THE HAY'S DISSOLVED OXYGEN ANALYZER.

Since the water and gas are being intimately mixed together at a rapid rate and a small volume of gas is continuously passing through the analyzer, the partial pressure of the oxygen in the gas phase is continuously determined at equilibrium. The recorder is calibrated to read in terms of the percent of saturation of dissolved oxygen, or it may be temperature compensated to read directly in ppm of dissolved oxygen.

For review, percent saturation of dissolved oxygen is equal to the actual amount of dissolved oxygen present divided by the amount of dissolved oxygen at equilibrium, or it is equal to the dissolved oxygen actually present divided by the amount that can be present at equilibrium. The measurement of dissolved oxygen in percent saturation is a relative measurement as opposed to an absolute measure when we place the dissolved oxygen concentration in ppm. Dissolved oxygen in its percent saturation, is independent of effects due to temperature, total pressure, salt content and total solids. On the other hand, a ppm measurement is absolute, and is dependent upon the aforementioned variables.

The analyzer (Figure 63) requires no calibration gases since it can be zeroed by removing the magnetic field from the detecting spirals causing a balancing of the measuring bridge. Calibration is provided by passing air through the analyzer which is equivalent to 100% saturation. This is done by switching a three way solenoid valve to introduce air into the analyzer.

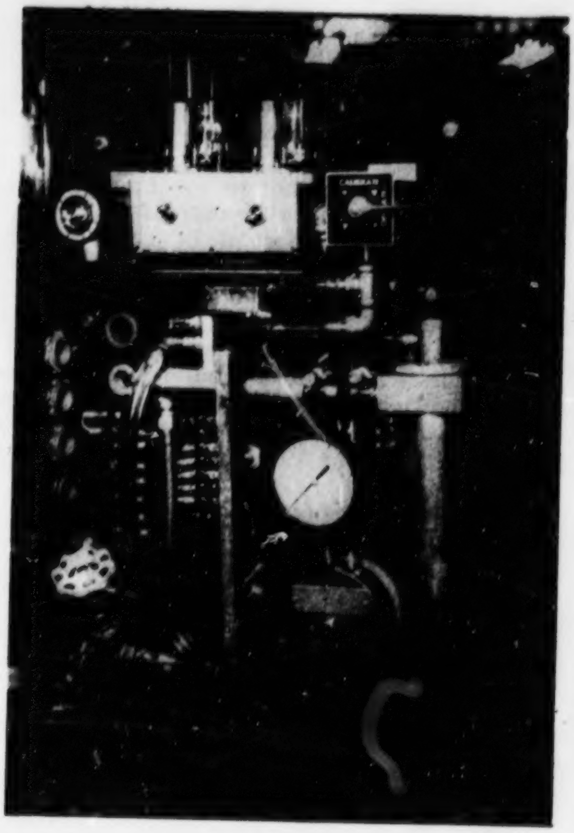

Figure 63. PHOTOGRAPH OF THE HAY'S D.O. ANALYZER INSTALLATION.

A pair of electrodes are installed at the inlet of the by-pass to the analyzer to provide a fail-safe or flood shut-off in event water fills the gas lines. These electrodes, upon contact with water, cause a relay to shut down the pump or close a solenoid in the water system to prevent damage to the analyzer.

One thing that is not illustrated on this schematic, is the temperature compensation to convert the reading of percent saturation into absolute measurement in ppm. To do this, a thermistor is inserted into the body of the water-gas separator to measure the water temperature. This thermistor provides a variable resistance which is proportional to the temperature condition of the water and corrects the span of the recorder for any deviation in temperature.

APPLICATION

The previous discussion has been involved mostly about the theory of the dissolved oxygen analyzer, so at this time, I would like to discuss some of the applications of the instrument that I think are unique.

1. Figure 64 shows a portable D.O. Analyzer in operation in a sewage plant located in the South East. The analyzer has been operated continuously on an activated sludge containing 10,000 ppm solids. What was most interesting to me, was the fact that the plant personnel at the station were unaware of the low concentration of the dissolved oxygen present in the system, This has been a significant point in all installations, DO's are lower than expected.

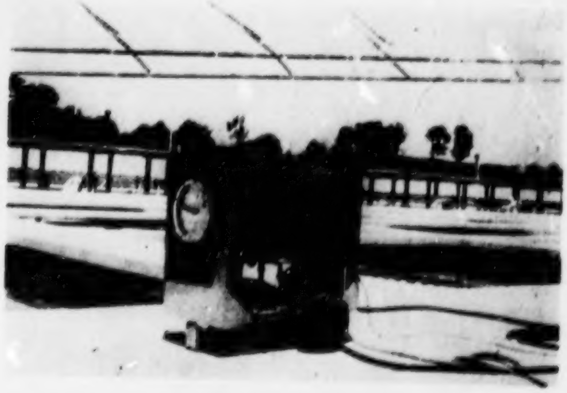

Figure 64. A PORTABLE D.O. ANALYZER.

2. Mr. Everett Knight, from the Public Health Service in Raleigh, North Carolina, used this analyzer as a means for developing a chemical analysis for dissolved oxygen in swamp water. You may be acquainted with the fact that tannin in swamp water interferes with the Winkler method of dissolved oxygen analysis, causing much lower dissolved oxygen readings than expected. Mr. Knight was concerned because fish were living in water that constantly gave zero results for dissolved oxygen by the Winkler method. The Hay's Dissolved Oxygen Analyzer was operated on this water and gave readings he felt were reasonable. Since the partial pressure of oxygen is not affected by the presence of the tannin, he assumed that the analyzer was reading correctly and worked on the analysis to correct for the tannin-induced error. He was successful and a paper covering his results will be published shortly. This is the only occasion that I know where an instrument was used to develop a chemical method of analysis to check the instrument accuracy.

3. Several tests have been run on river quality with this unit. The Delaware River at Philadelphia had an extended test covering several months (Figure 65). DO values varied from zero to 70% saturation during the test. These evaluations of river pollution are only the first of a series planned by the Delaware River Basin authorities. Other tests are now being run on the Roanoke River by the State of North Carolina.

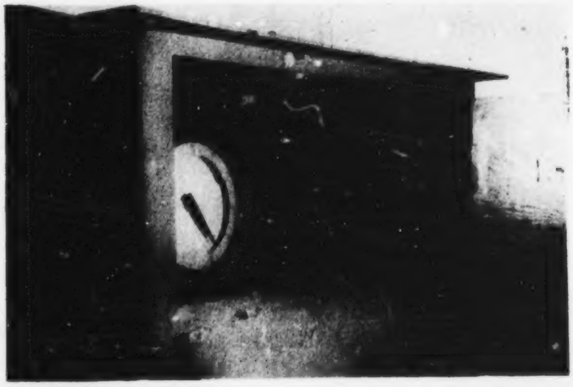

Figure 65. A HAY'S D.O. ANALYZER INSTALLED AT PHILADELPHIA.

4. As a last example of applications we encountered, a power company operating on the East Coast, is required by the law to pass a certain number of pounds of oxygen down stream of the power dam daily. There is no problem when flows are high, but during low river flow rates, aeration of the water as it passes through the turbines is necessary. A continuous operating dissolved oxygen analyzer furnishes information essential to this operation. A simple calibration of flow rate, times the concentration of DO, allows the operator to control the river oxygen concentration downstream from the dam.

There are other instruments that are valued stream purity monitors as you are well aware. In fact, the Delaware River Basin Authority is considering over a dozen stations along the river to monitor the following variables:

1. Dissolved oxygen.
2. Water temperature.
3. River flow rate.
4. Sun light intensity.
5. Turbidity of the water.
6. pH.
7. Conductivity of the water.

Several of these variables are reflected directly into DO concentration such as lighting intensity (micro organism growth with photosynthesis), temperature, and indirectly, pH and conductivity.

"Waste dumps" by industrial plants cause large variations in the last two items, pH and conductivity. These "dumps" usually result in an increased oxygen demand causing low dissolved oxygen.

Considering the number of analyses that are accomplished by these instruments, it is apparent that either a high degree of reliability must be obtained with the instruments, or competent and available service personnel will have to be present at these stations. I wish I could say that infallibly reliable instrumentation is available for all of these analyses; but, it is not. Plenty of work remains to be done before we can rely completely on telemetering equipment to report the station conditions. It is definitely going to come to pass that these unmanned stations will exist, but until recently very little pressure has been applied in this direction.

There are several different types and principles used for each of these analyses, but few "systems" are in use which try to consolidate all of these analyzers into one arrangement. Our company has attempted this to a small degree with what we term the Universal Recorder (Figure 66). An attempt has been made to receive up to four different independent signals in one recorder. These may be, for example, temperature, dissolved oxygen, flow, and pH. Because of the particular arrangement, various signals may be received and the recorder used as a computer. As an example, for the problem of maintaining a constant poundage of oxygen downstream from the dam I mentioned previously, a signal of flow and ppm Oxygen with a multiplier circuit can give read-out and record in total pounds of oxygen over the dam. Other advantages of this system are recording four variables on one recorder chart which simplifies record keeping.

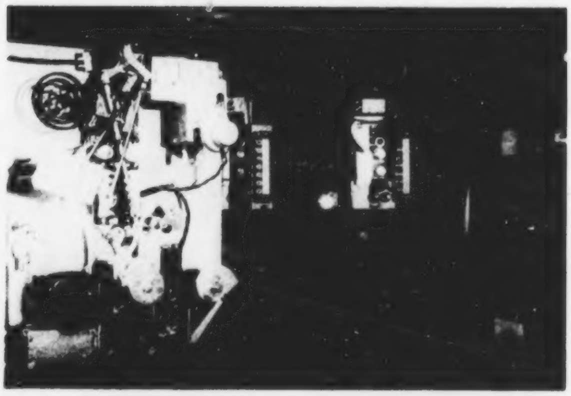

Figure 66. THE UNIVERSAL RECORDER.

CONCLUSION

The object of my discussion has been to acquaint you with the fact that there is now on the market a dissolved oxygen analyzer capable of continuous operation in practically any type of surface water. This analyzer when associated with other important variables, temperature, flow, pH, turbidity, and salinity, offers valuable aids in improving and insuring future stream purity as our waste waters increase in future years. I think that more and more pressure will be exerted on instrument manufactures to produce a "fool-proof" line of analyzers for this purpose. At this date, we are only in the infancy of the aforementioned instrument program. I hope that meetings such as this, with manufacturers, public health officials, waste disposal plant operators, and other informed personnel, will lead to better, more reliable instrumentation in this vital field.

RECENT ADVANCES IN THE CONTINUOUS RECORDING OF THE ELECTRICAL CONDUCTIVITY OF SURFACE WATERS

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The need for and the significance of conductivity data has been well established in stream and ground water survey work and a few moments could be well spent to review the mechanics of obtaining this data and to discuss the weak and strong points of each method. The oldest and most common method is to return samples to a central laboratory and make the measurements there. The samples are gathered either by paid-on-the-spot observers, such as local residents, or by laboratory personnel during periodic visits. These are the least expensive of the various methods of obtaining conductivity data but there are disadvantages. The final information suffers from large gaps since the samples are representative only of what is happening at a particular instant and at that particular location.

In-situ tests have both advantages and disadvantages over collecting grab samples and returning them to central laboratory. To approximate continuous sampling for any period of time at even one location can become prohibitive from a cost standpoint. This is due to the cost of maintaining one or more operators on a round-the-clock basis at the sampling point. In addition, the samples are still of a non-continuous nature. On the plus side of this type of arrangement, the readings are immediate and any variations or discrepancies can be quickly double checked. In many cases, cross sectioning or taking a profile of the body of water involved may be beneficial and several special instruments have been developed for this purpose. Another advantage of in-situ measurement is that observations, such as rain storms, etc. may be added to the record. This supplementary data is many times of value in clarifying apparent discrepancies in a series of readings.

A continuous record of solution conductivity is fundamentally the only way to make data significant. Many times the conductivity changes are aperiodic in nature and these changes must be correlated with other phenomena to make them meaningful. It is true that there are disadvantages with a permanent record, such as possible loss of record due to malfunction of the equipment through vandalism or other causes. There is also no way of determining the instantaneous accuracy of the record although this may be approximated by checking the instrument accuracy at both the beginning and end of the recording cycle. The disadvantages however, are far outweighed by the many advantages. To mention a few, the most important is that a continuous time profile is presented for permanent record. Many times significant data appears over short time intervals and is easily missed by a grab sampling system. A second advantage is the long time reduction in cost of data collection since all of todays' instruments may be expected to give long trouble free performance from the initial investment. In a case for example, where salt water intrusion is a problem, a multi-point instrument may be readily utilized to give not only a continuous time profile in a location but, by placing several conductivity cells at various depths, the amount of mixing which takes place between the more dense saline water on the bottom of the stream and the fresh water at the top may be studied.

A number of different types of instruments are available, each suited to an application by virtue of its special features. Laboratory bridges are usually line operated and their accuracies range from 1% to about 0.1%. These bridges are priced between $200.00 and $1,000.00. Uusually these instruments are fairly complicated and require skilled operators for best results. A few bridges of an order of magnitude of accuracy higher have been built by individuals for their own use but almost without exception these are exceedingly cumbersome and difficult to operate.

Going to the other extreme, there are portable field instruments designed for use either at the waters' edge or in a small field laboratory. Most of these instruments are battery powered but some are AC line powered and these latter may be operated alternatively from a storage battery by the use of a small vibrator type converter.

Direct reading meter type instruments are often preferred for field use because of their simplicity of operation. Unfortunately, the simplicity of the instrument is not without its drawbacks. The accuracy of measurement varies over the range of the meter and in addition the reading is affected by variations in battery voltage. Another problem is the susceptibility of the meter to mechanical shock.

A null balance Wheatstone Bridge eliminates these problems, is basically capable of higher accuracies but does require that the operator judge the null point on some type of a null balance indicator. This indicator may take the form of the absence or presence of a tone in a pair of headphones, a visual indication such as a tuning indicator type vacuum tube or a zero center meter. Very often the sharpness of the null balance of the bridge may be used as an indication of the general condition of the conductivity cell.

A direct reading meter display instrument is used extensively by fisheries research people for whom 10% accuracy is usually sufficient. This battery powered instrument costs about $100.00. Battery powered null balance Wheatstone Bridge type instruments of better than 5% accuracy are available where the higher precision is desirable. The cost of these instruments is close to $150.00. A special version of this instrument has been developed for harbor surveys and similar applications where both conductivity and temperature may vary with depth and both are of interest. This instrument is capable of reading conductivity corrected for temperature, and temperature as well, as the weighted conductivity cell is lowered into the water. The cost of this instrument is approximately $500.00.

Line operated recorders have seen extensive service in the past five years in stream surveys in locations where AC power is available. With the exception of some minor difficulty in obtaining inks of proper characteristics, such recorders have given outstanding service for protracted periods of time with very little maintenance. This includes both single and multi-point instruments where the instrument may be located conveniently close to several points of interest such as above and below a suspected source of pollution. Multi-point instruments are also used extensively with several cells at various depths in tidal waters where considerable variations in conductivity and temperature may occur. Another application for multi-point instruments involves several cells of different cell constants at the same location. This allows good readability on each range without sacrificing overall range. Obtainable accuracies are in the order of 2% and prices start at $900.00 for a single point instrument. Multi-point instruments run only slightly higher.

Most rivers and streams unfortunately are not wired for AC power and until fairly recently obtaining a continuous record of the conductivity in remote areas was difficult if not impossible. Several years ago we made an estimate to determine what might be required in the way of lead acid storage batteries sufficient to run a standard AC operated recorder for a period of one month without attention. An answer of 7-1/2 tons of batteries made the project somewhat less than feasible. At about the same time, Mr. Norman Beamer of the Philadelphia Office of the Geological Survey asked us to look into the possibility of supplying him with a relatively small portable battery operated recorder capable of 30 days unattended use whose cost would be comparable with line operated units. More than a year's development time was required to provide an instrument which meets and exceeds these requirements. The instrument is housed in a 14 x 12 x9" gasketed metal case and weighs 25 lbs. including batteries. It is capable of operating for periods up to one month without attention. The chart is driven by a standard hand wound clock-work mechanism with interchangeable hubs for various rotational chart speeds. The electronic portion consists of a very low current drain transistorized amplifier assembly and AC Wheatstone Bridge operating on the null balance principle. This insures complete freedom from the effects of external temperature and battery voltage variations. The instrument is divided into sub-assemblies, each of which is of plug-in construction for ease of servicing.

The Wheatstone Bridge components are also of plug-in design in order that the range may be changed in a matter of minutes. The accuracy of this instrument is within 3% and the overall cost is between $700.00 and $900.00. Many of these instruments are employed on the Delaware River, on both salt water intrusion and stream pollution surveys from the Delaware Bay northward over the entire northeast portion of Pennsylvania. An even greater number are employed over a 300,000 square mile area encompassing the Red River and Arkansas River Valleys in northern Texas, Oklahoma and Colorado.

Considerable effort has been expended over the past twenty years in the field of electrodeless conductivity systems. Many systems have been developed utilizing a capacitive type of conductivity cell, measuring the conductivity of the water sample as a loss factor in a capacitor. The capacitive type instruments are not direct reading, usually difficult to operate, and generally far from satisfactory. Recently a good deal of work has been done in measuring conductivity by an inductive rather than capacitive method. At least three different instruments have been developed utilizing this principle in an effort to eliminate some of the problems which arise from the use of conventional electrode type conductivity cells. To my knowledge however, none of the instruments are in continuous service in the stream sampling field. Generally this type of instrument is more useful in the high conductivity ranges and two of the three models are being used in oceanographic work where sea water rather than surface water is the electrolyte. The third instrument is in continuous service in the industrial chemical field measuring such materials as concentrated alkalies or acids or fused salts. The cost of the induction type electrodeless conductivity system is about 5 to 10 times that of a manually operated null balance AC Wheatstone Bridge system and may contain from 8 to 16 vacuum tubes and their attendant electronic components. The large number of electronic components necessary for a system such as this, coupled with the usually severe environmental requirements which are encountered in outdoor installations definitely have a marked effect on the reliability factor of such a system.

In the induction conductivity measuring system, the liquid under test forms all or part of a closed loop. This loop passes through the center of a toroidal coil which is connected to a source of AC power. A voltage is induced within this solution loop and a circulating current consequently flows around the loop. The magnitude of the current is a linear function of the conductivity of the liquid within the loop. A second toroidal coil threading the loop functions as a current transformer, producing a voltage exactly proportional to the conductivity of the liquid.

The interest in non-electrode type conductivity measuring systems has developed through efforts directed to reduce some of the maintenance and fouling problems which are encountered with conventional electrode type conductivity cells. At present, it is recommended that conductivity cells be cleaned about monthly. This is due to deposition of solids and growth of algae upon the cell bodies and electrodes. The elimination of electrodes does alleviate the problem of coating of the electrodes themselves but does not eliminate the problem of the changes in physical dimensions of the cell passages. The cell constant of any type of conductivity cell is directly related to the dimensions of these, and deposition of solids in the cell will reduce internal diameters and also block circulation. One example of this occurred when the record of a cell located in tidal waters showed variations in conductivity which bore little or no relationship to the tidal cycle. Examination of the cell revealed a shrimp lodged between the electrodes. When the shrimp was at home the apparent conductivity was low since he was blocking the passage. When the shrimp went out for lunch, the conductivity went up. This and similar examples indicate that further improvement is needed in the design of conductivity cells to make them self-cleaning and perhaps show a reduction of algae growth through the inclusion of inhibitors. Changes in mechanical design to reduce errors due to fouling and solids build-up through de-emphasis of critical dimensions are also desirable.

In the field of instrumentation, the one major continuous improvement is in the field of reliability. Another area of possible improvement is the combination of recording devices with other instrumentation for either automatic control or improved data gathering. For example, a recorder could be readily combined with an automatic sample collection device so that a complete analysis may subsequently be run on a sample taken during abnormal stream conditions. Another possible area of improvement is the coordination of stream monitoring instruments into process control systems in water treatment plants. A conductivity cell placed upstream from an intake could initiate changes in the treatment well in advance of the arrival of any abnormal dissolved solids at the treatment plant intake. Other areas of improvement lie in the coordination of conductivity measurements with other measurements in order that variations in a number of quantities may be recorded simultaneously at central locations by telemetering techniques. We would thus obtain a better picture of the changes occurring over a wide area, and at the same time get a more detailed record at each location. An approach of this nature will certainly assist in the conservation of our most valuable and yet most wasted asset, water.

AUTOMATIC SURVEILLANCE—AN OPERATING SYSTEM

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SUMMARY

We report herewith progress on an automatic system for appraising water quality on a round-the-clock basis in the Delaware River. Provisions have been made for automatic sampling and warning upon significant departures from the normal values of the selected variables.

Additional objectives are the collection of basic data on water quality of the Delaware River and studies on the interrelated influences of the measured variables on the complex biological sequences in the river. Presently, the variables measured are pH, oxygen, conductivity, temperature, turbidity and sunlight intensity. Findings, presented in graphical form, indicate the more evident interactions of these parameters.

INTRODUCTION

With a clearly prophetic vision, Saville in 1935 (1) defined the basic needs for a national program of water quality data and characterized water uses in an expanding technological society. Reference was made to water needs by citations from Ecclesiastes and Justice Holmes.

Implementation of these concepts is evident in the papers by Green (2) and Palange and Megregian (3, 4). We have therefore a functional National Water Quality Network (5) with the cooperation of Federal and State agencies, municipal and private water companies and several industries.

Several of the determinations in the National Network lend themselves to automation. It is the purpose of this paper to present developments and data on an automatic system, for certain water quality parameters, developed by personnel of the Water Resources Research Council of Lehigh University under the sponsorship of the Interstate Commission on the Delaware River Basin. It is appropriate here to give due recognition to the achievements (6) of personnel of the Ohio River Valley Water Sanitation Commission at Cincinnati in the development of a river "robot" for detection, measuring and telemetering of certain parameters indicative of water quality.

The National Water Quality Network assembles data on more than twenty parameters (5) which include chemical, physical, biological and certain radiological characteristics. In the present state of the art, many of these do not lend themselves to automation nor is it expected that it may be economically feasible to evaluate all of these variables without human intervention.

THE BASIC APPROACH

Biologists, long confronted with the problem of obtaining adequate data on aquatic environments are aware of the evident limitations of "grab" and "pooled" samples. It is sufficient to state that the former defines a variable at the moment of sampling and that the latter yields only an average value. Manual collection and analyses of samples on a continuous basis is expensive even when graduate students are employed.

We therefore sought instrumental methods for those parameters yielding data pertinent to aquatic biological characteristics and capable of recording natural cyclic variations in these parameters.

It soon became evident that a feasible automatic system would furnish interrelated data on the complex biology of a river and would also serve to detect marked departures from "normal" values. In addition, provisions could be made for automatic sampling and warning when such departures were recorded. Thus was developed the concept of automatic river surveillance and it is recognized that this principle, as applied to chemical process control, is old in the state of the art.

Literature searches were made on the various analytical procedures which had been or might be made automatic. In addition we recognized that certain criteria, e.g. coliform counts, B.O.D. measurements, and evaluation of planktonic forms might remain as manual determinations. To the twenty odd variables included in the National Network may be added several which are of concern in particular industrial situations. In tabular form, the following are listed as suitable for recording by automatic instrumentation. It should be noted that, at present, some of these are reliable only when frequently checked by competent laboratory personnel.

Variables Presently or Potentially Recordable by Automatic Instruments:

Variable,	Recorded in terms of
1. Temperature,	°C or °F
2. Conductivity,	micromhos
3. Oxygen,	parts per million (ppm)
4. Turbidity,	Jackson Candle Standard
5. pH,	log 1/H concentration
6. Sunlight Intensity,	gram-calories/sq. cm./minute
7. Total Hardness,	ppm $CaCO_3$
8. Methyl Orange Alkalinity,	ppm $CaCO_3$
9. Phenolphthalein Alkalinity,	ppm $CaCO_3$
10. Carbon Dioxide,	ppm
11. Chloride Ion,	ppm
12. Residual Chlorine,	ppm

13. Cyanide Ion,	ppm
14. Fluoride Ion,	ppm
15. Chemical Oxygen Demand,	ppm
16. Phenols,	parts per billion (p. p. b.)
17. Color,	Platinum - Cobalt Standards
18. Oxidation - Reduction Potential,	Millivolts
19. Alpha and Beta Radioactivity,	micro-micro curies/liter

An instrumental tour-de-force is illustrated by the work of Kieselbach (7) on an automatic system for the determination of oxidizable carbonaceous material in waste water.

THE INCODEL MONITORING SYSTEM

In our early work on monitoring of water quality, we selected four variables which were recordable on standard commercial instruments. The variables were: temperature, pH, conductivity and oxygen concentration. For the first three, there was existing, reliable sensing and recording equipment. Initially, there appeared no reliable method for the automatic determination of oxygen. We were aware of developments of two methods which appeared to have promise. These were the gas-equilibrium and the electrochemical methods. These methods and two other possible approaches are discussed in our previous paper (8) and in the detailed reports to the Interstate Commission on the Delaware River Basin. We developed a dependable dropping mercury electrode based on the design of Briggs et al (9) and found certain manipulative objections.

The availability of the Carritt-Kanwisher Electrode (10, 11) simplified certain difficulties in polarographic oxygen determination but presented problems of temperature compensation, flow response and sensitivity to radiant energy. The latter two problems are solved by adequate minimum flow over the platinum electrode and by the exclusion of light. For temperature compensation, the use of thermistors is obvious. However, we are not currently aware of the commercial availability of thermistors of appropriate shunting resistance range and above 4.8% change in resistance per degree Centigrade.

A resistance change of about 6% per C° approximates the upper limit of temperature effect upon the diffusion current which is a function of oxygen concentration. We have designed a bi-metallic helix driven attenuator and we are aware of other possible methods of adjustable temperature compensation. These methods, now under development, will, it is expected, reduce the temperature error to about one percent. Those with experience in repeated field analyses by the conventional Winkler method, or its many modifications, will accept a latitude of plus or minus 2.5 percent! Meanwhile our recorded values are checked by Winkler analyses and corrections are applied. Figure 67 shows the circuit which we are using to transfer the output of the oxygen electrode to the circular chart recorder.

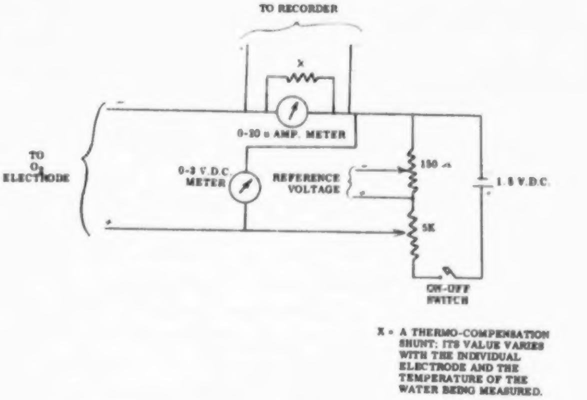
TO RECORDER
X
0-20 μ AMP. METER
TO O_2 ELECTRODE
0-3 V.D.C. METER
REFERENCE VOLTAGE
150 Ω
1.5 V.D.C.
5K
ON-OFF SWITCH
X = A THERMO-COMPENSATION SHUNT: ITS VALUE VARIES WITH THE INDIVIDUAL ELECTRODE AND THE TEMPERATURE OF THE WATER BEING MEASURED.

Figure 67. OXYGEN ELECTRODE RECORDER CIRCUIT.

It was planned to discuss the gas-equilibrium method of oxygen determination as this method, in its pioneering phases, was developed at the Taft Center. Since adequate coverage of this instrument is included in the program, we omit this item. It is appropriate, however, to note that the instrument as presently operated has high promise as a dependable method of oxygen determination.

It is now appropriate to discuss two additional recordable variables viz: turbidity and sunlight intensity. In our preliminary plan of automatic monitoring we contemplated the use of a transmission type turbidimeter. It was evident that maintenance, particularly the cleaning of the transmission cells, would make this instrument very sensitive to the periodic and non-predictable variations in the suspended silt load of the Delaware River. In addition the instrument was very expensive even in a simplified version. We therefore abandoned turbidity measurement. In April 1959, we learned of the development of a reflectance type turbidimeter and observed this in operation at the ORSANCO laboratory. One of these turbidimeters was installed during November 1959 in our field test facility which will be subsequently described. We devote no space to the details of this reflectance type turbidimeter as this is the subject of a paper at this symposium.

For the measurement of sunlight intensity we have selected a standard pyrheliometer. This is a "ten" junction Platinum-Rhodium thermocouple assembly (12) and has been calibrated in millivolts output per gram-calorie per square centimeter per minute. The purpose of recording sunlight intensity is to correlate this variable with photosynthetic oxygen production and oxygen utilization by microorganisms responding to organic pollutional load.

OTHER RECORDABLE VARIABLES

Reference is now made to the tabulation above which lists variables recordable by instrumentation. Items 7 to 16 are determined by automatic measurement of an end point. In each case, a controlled feed of titrant or colorimetric indicator or both are required. For Chloride ion an alternate approach is provided by the Silver Chloride-Silver electrode described by Noebels (13). It is of value to note that this electrode serves to differentiate chloride ion from total conductivity in saline environments where inorganic pollutants other than chloride ion exist. A theoretical alternate method for the measurement of CO_2 is provided by the special pH sensitive CO_2 electrode reported by Severinghaus and Bradley (14). A variety of titrimetric methods are discussed in the Symposium on Automatic Chemical Analyses (13).

THE RIEGELSVILLE MONITOR STATION

After extensive laboratory testing we installed a prototype station on the Delware River at Riegelsville, New Jersey. The details are described in our previous publication (8) and it is pertinent here to state that the equipment is installed in a weather proof building. Water is pumped into the sensing elements by a standard deep well pump mounted upon a Sigafoos float assembly. Heating cables and insulation protect the piping during cold weather. We are currently investigating modifications of the circuitry with a view toward simplification of the timing circuits, the sequential switching assemblies and the automatic surveillance features. These as presently set will record departures in pH below 4 or above 9 and for conductivity above 225 micromhos. The present circuit requires abnormal departure for both pH and conductivity simultaneously to activate the sampling solenoid.

INTERPRETATION OF THE GRAPHS

As has been previously mentioned, the monitoring station at Riegelsville, New Jersey records six variables which can be used as indices of water quality. No one of these variables alone would serve as an indicator of aquatic conditions, however, collectively they can tell a significant and rather interesting story. The necessity for collective consideration of the six parameters arises directly from the fact that all of the variables are closely interrelated and thereby account for the multitude of variation included under the title of water quality.

Commonly there are many biological processes occurring simultaneously in a body of water such as a river; in this particular discussion interest will be directed at just two of these processes, namely respiration and photosynthesis. Respiration occurs in all living organisms, plant and animal, and is defined as the oxidation of food materials resulting in the release of energy utilizable by the organism, with carbon dioxide and water being given off as by-products. Photosynthesis which on the other hand occurs only in green plants, utilizes carbon dioxide, water, and energy from the sun to synthesize sugars which can be transformed into energy for the other metabolic processes of the plant, or the sugars can be stored in one of several forms; oxygen is a by-product of the photosynthetic reactions.

During the dark period of the day respiration alone, of the two processes, takes place: hence the concentration of carbon dioxide in the water gradually increases. This increase in the carbon dioxide concentration is reflected in both the pH and conductivity recordings. Carbon dioxide reacts with the water forming carbonic acid, which being only slightly dissociated only moderately affects the pH and conductivity of the water. The above-mentioned effects can be clearly seen in Figure 68. The diurnal pH change is evident throughout the entire graph, the extent of the daily change being approximately 0.5 pH units. The cyclic conductivity change is masked by the other factors for the majority of the plotted interval, however if notice is taken of the period July 12-15, the cyclic change is clear, being in the order of 15 micromhos.

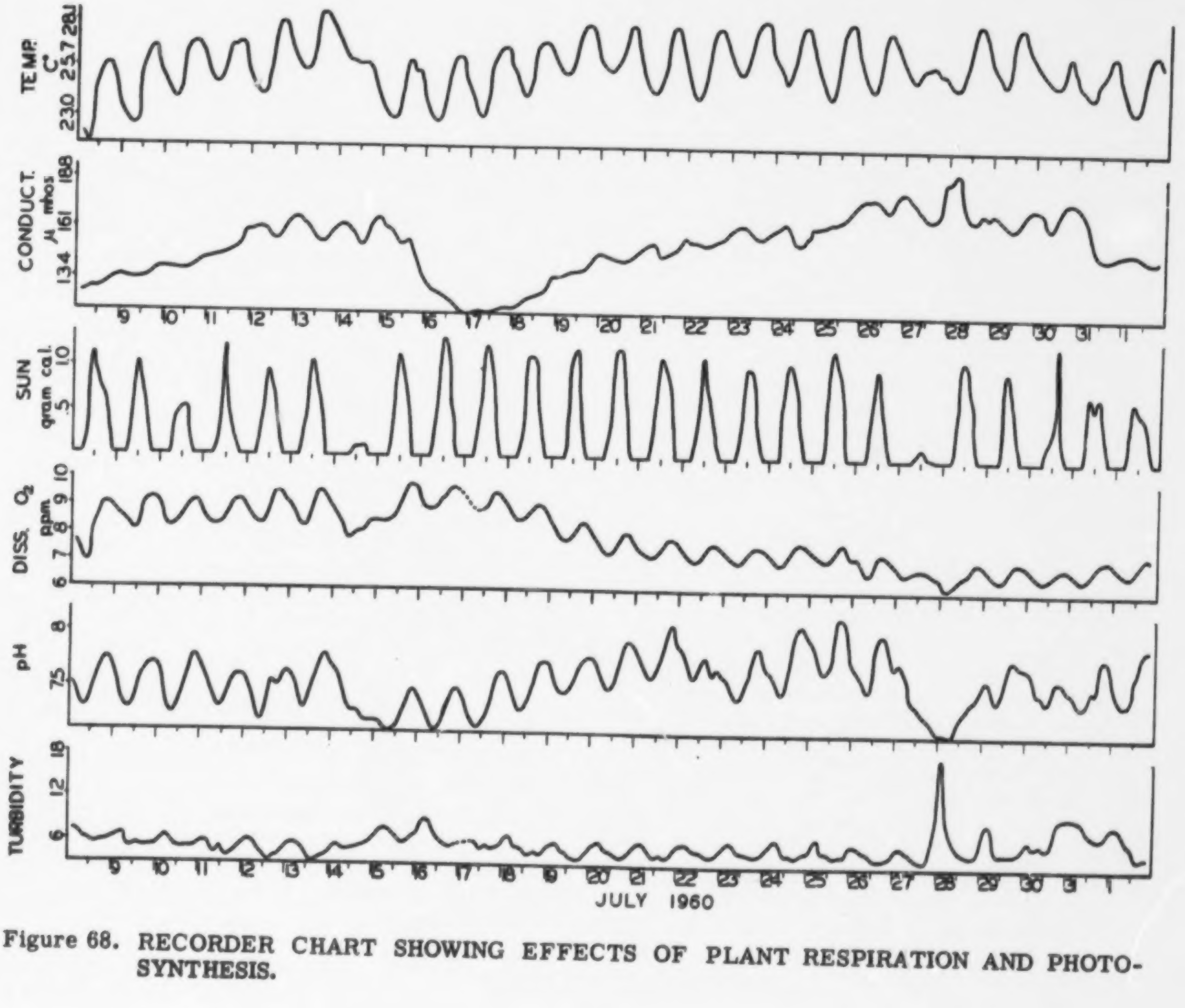

Figure 68. RECORDER CHART SHOWING EFFECTS OF PLANT RESPIRATION AND PHOTOSYNTHESIS.

During the daylight hours photosynthesis occurs concomitantly with respiration and in fact proceeds at a much higher rate than does respiration. The resultant effects of photosynthesis are a sharp rise in the dissolved oxygen concentration and a decline in the carbon dioxide content. These changes can again be most clearly seen by referring to Figure 68. The cyclic fluctuation in dissolved oxygen concentration is pronounced, with variation on a warm sunny summer day being in excess of two parts per million. The high rate of photosynthesis will rapidly take up the carbon dioxide in the water resulting in a decrease in the conductivity and an increase in the pH as the carbonic acid dissociates to carbon dioxide and water. (The long and short bars across the abscissa of the graphs are 12 hours apart with the short bars being noon of the day indicated by the date immediately to the left of the small bar.)

The remaining recorded variables (i.e. turbidity, temperature, and sunlight) might be referred to as "analysis-aids" for the interpretation of an "abnormal" deviation in pH, dissolved oxygen, or conductivity. Turbidity is of course very important to the photosynthetic activity of the river. If there is a great deal of suspended inorganic material in the water, the sunlight can not penetrate as deeply into the water and the photosynthetic rate will be reduced, resulting in decreased oxygen production and carbon dioxide uptake. There is no really clear example of the effect of increased turbidity in Figure 68; however, if the reader will look at the records from July 28, 1960, to the end of the graphs, which was a rainy period, it will be noted that the turbidity readings are slightly higher and the pH and dissolved oxygen are more depressed than the preceding ten days. The daily cyclic variation in the turbidity record is believed to be caused by migrating planktonic organisms; the causes and relationships involved are now under study. The turbidity scale ordinate is in "Hach" units for ease of plotting from the monitoring station recorder. The relation between "Hach" units and the standard Jackson Candle Turbidimeter units is as follows: if turbidity units are plotted logarithmically against millivolt output in a linear fashion, in the range between 25 and 200 Turbidity Units the millivolt recording is linear up to 20 millivolts.

The recording of temperature is important here for two reasons. The rates at which the normal biochemical metabolic processes of the aquatic organisms proceed is directly related to water temperature. In addition, a rapid change in environmental temperature can be lethal to various numbers and types of aquatic organisms with the actual effect being dependent upon the duration, extent, and rate of the temperature change. The daily cyclical fluctuation of the river temperature which is obvious in Figure 68 is a result of the diurnal solar heating and the subsequent nocturnal cooling as heat is transferred to the atmosphere. The cycle is pronounced on the graph because the sampling pump draws its sample from a depth of two feet beneath the river surface.

Sunlight is recorded primarily to provide meteorological data used as an aid in the interpretation of possible unnatural deviations shown on the records of the other variables. To be more explicit--on July 14, (Figure 68) the pH dropped, oxygen curve is flat rather than having the normal mid-afternoon peak, and the temperature dropped nearly five centigrade degrees from the peak temperature of the previous day. One might say, with some justification, that an unnatural pollutant had entered the river by some nefarious means; however, reference to the sunlight, turbidity, and conductivity records would make the diagnosis of pollution much less plausible. The sunlight record for July 14 shows a heavily overcast day, turbidity shows a slight increase, conductivity shows a sharp decline beginning on July 15th; these together with the pH, dissolved oxygen, and temperature data give all the indications of rain, which in actuality did precipitate the above described changes. It may be noted that the shape of the sunlight curve is in reality a normal "bell" curve. It has been distorted in Figure 68 because the points plotted were taken at three hour intervals and the abscissa has been compressed.

Figure 68, in general, gives a rather clear picture of a reasonably unpolluted river showing the relationships between the measured variables under natural conditions. Normally during the periods without rain there will be a daily cyclical fluctuation in all the variables described above for the reasons noted; the magnitude of the fluctuation being greater during the summer than the winter. Between periods of rain, in the summer especially, the conductivity of the river will gradually increase as evaporation concentrates the ionic constituents in the water. After periods of rain it can be expected that the conductivity will fall rapidly because of dilution of the ionic materials, the oxygen will level off for the duration of the rainy period, the pH will drop slightly because of the absence of photosynthesis (excluding, of course, any change brought about by the rain flushing some very acid or alkaline material into the river), and finally the turbidity will increase in various degrees depending on such factors as how much rain falls and whether the moisture is absorbed by the land or quickly runs off causing flooding of the tributary streams and the consequent bottom scouring turbulence.

The foregoing rather neat picture can be modified however, and the relationships then change somewhat. An example is the rain that fell on July 27, 1960, (Figure 68). The expected changes occurred except for conductivity which increased rather than decreased. The increase in conductivity is attributable either to ionized pollutants or to the very sharp increase in the turbidity. The particular rain in question was quite heavy and did not soak into the ground, but ran off rapidly causing flooding of the tributary streams and, in turn, of the main river. The flooding and accompanying turbulence carried a great deal of silt and soil into the river and evidently the concentration of ionic material actually increased for a short period. It can be seen that the initiation and termination of the sharp turbidity peak and the less "dramatic" conductivity peak correspond quite precisely.

Figure 69 (June-July 1959) shows quite clearly a conductivity peak on July 12, 1959. This peak occurred during a rainstorm. In this case we are of the opinion that ionized material was dumped into the river during the storm. The decision was made because of the magnitude of the rise (approximately 90 micromhos) and because it was a slow steady rain which caused little or no tributary flooding with the accompanying enhanced turbulence.

Figure 70 (August 1959) shows very little new information. There are however two conductivity peaks, one on August 6, the other on August 9. These were also during a period of rain and are believed to be man-caused ionized pollution, because of their rapid rates of increase and decrease and also because of their short duration.

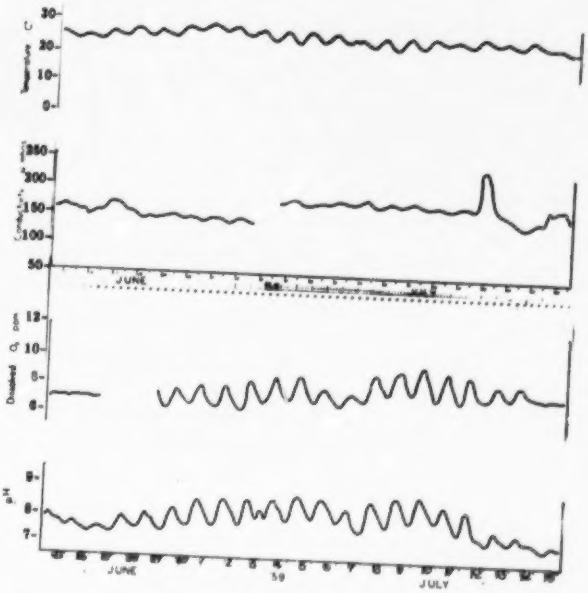

Figure 69. CONDUCTIVITY CHART WITH RELATED DATA, JUNE-JULY, 1959.

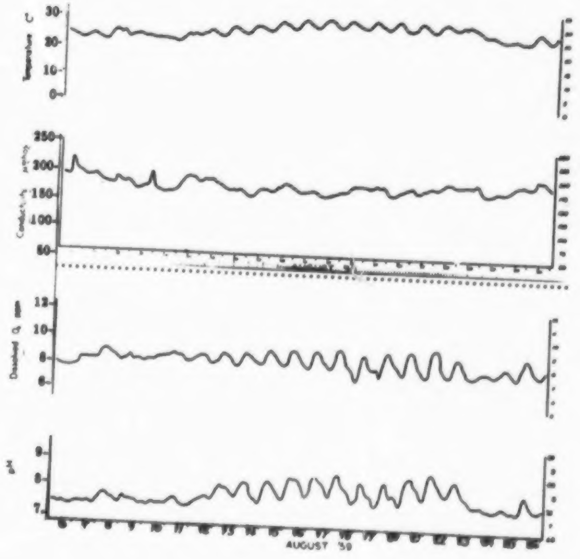

Figure 70. CONDUCTIVITY CHART WITH RELATED DATA, AUGUST 1959.

FUTURE MONITOR PLANS

Figure 71 shows the presently planned network of eleven Incodel monitoring stations in the Delaware Basin (15). The stations, in sequence, from the upper drainage are as follows:

A. Between New York and Pennsylvania: Hancock, Narrowsburg, Minisink and Port Jervis.

B. Between New Jersey and Pennsylvania: Montague, Broadhead's Creek, Martin's Creek, Easton, Riegelsville, Frenchtown and Trenton.

Of the eleven proposed sites, three are confirmed. These are the existing station at Riegelsville and the stations at Montague and Martin's Creek. It is expected that these last two will be in operation prior to January 1961.

In our preliminary planning we have also suggested local and minimal monitor sites for support by states or political subdivisions, on the rivers tributary to the Delaware River. At present eight subsidiary sites are suggested. These are as follows:

1. On the East and West branches of the Delaware River below Hancock, N. Y.

2. On the Lackawaxen River at Lackawaxen, Pa. It is relevant to report that the drainage here is derived from Lake Wallenpaupack, a large recreational area, and from the peak load hydroelectric plant of Pennsylvania Power and Light Co.

Neversink River at Port Jervis. At this site is a sewage plant, operated by the City of New York, for the City of Port Jervis, and in compliance with the initial permissive Supreme Court decree for diversion of water to New York City from the upper Delaware Basin.

4. Paulins Kill and Pequest River in New Jersey. These represent areas of mixed agricultural and industrial drainage.

5. The Lehigh River at Easton. This is the "Forks of the Delaware" and is critical in the pollutional load of the Lehigh Valley.

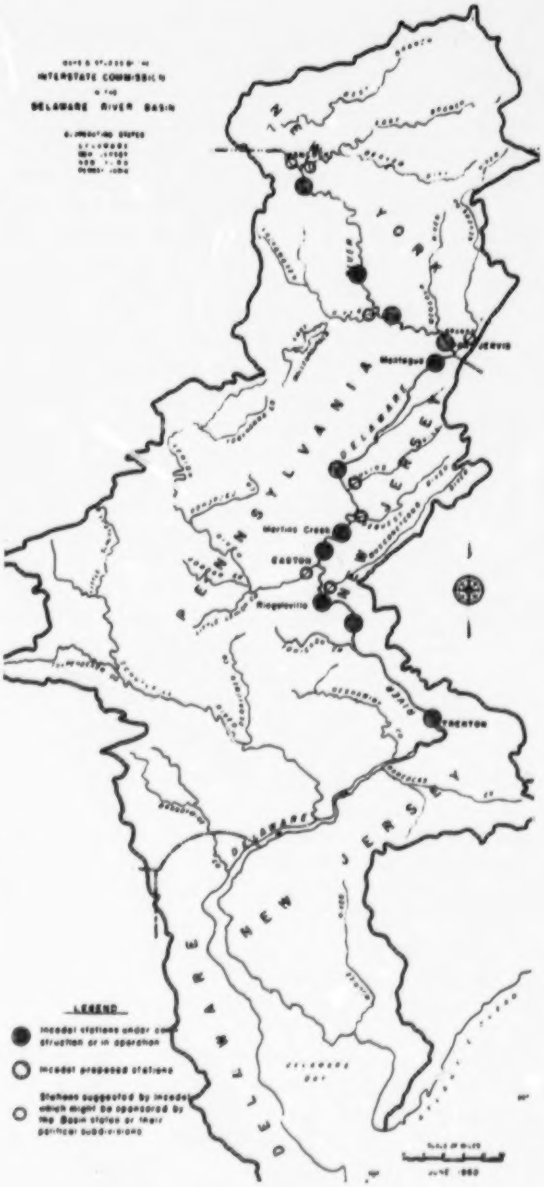
INTERSTATE COMMISSION
DELAWARE RIVER BASIN
NEW YORK
PENNSYLVANIA
NEW JERSEY
DELAWARE
Montague
Martins Creek
Easton
Riegelsville
Trenton
Delaware Bay
LEGEND
Incodel stations under construction or in operation
Incodel proposed stations
Stations suggested by Incodel which might be sponsored by the Basin states or their political subdivisions
June 1960

Figure 71. INCODEL PROPOSED NETWORK OF MONITORING STATIONS IN THE DELAWARE RIVER BASIN.

6. The Musconetcong River below Riegelsville, New Jersey. This tributary receives

variable discharge from three paper mills. It should be noticed that the proposed station at Frenchtown, New Jersey is below a fourth paper mill on the Delware main stem.

For the Delaware River below Trenton we expect detailed monitoring at appropriate locations by the City of Philadelphia in cooperation with the U. S. Geological Survey. In the lower bay, the State of Delaware has an active program including instrumentation on a boat and manual sampling.

It is evident that the most efficient method of following water quality in the Delaware Basin is by an interconnected network and telemetering to a central agency. Logically this is an INCODEL function and would serve to supply data obtained instrumentally and manually for the entire basin. For certain areas this would serve as a warning system to water plant operators, in sufficient time to revise their operations or to suspend intake and processing during a heavy pollutional load.

ACKNOWLEDGEMENTS

It is evident that this three-year research program could not have been pursued without the sustained interest and support by the Interstate Commission of the Delaware River Basin. Particular credit is due to Mr. James H. Allen, Executive Secretary, and Mr. John Boardman, Engineer, for assistance and advice. We also are grateful for technical help and administrative guidance by Professor George R. Jenkins, Director of the Institute of Research of Lehigh University.

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CONTINUOUS MONITORING OF RADIOACTIVE STREAMS*

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Along with nuclear power came the creation of radioisotopes in great abundance. This abundance of radioisotopes has found its way into laboratories, hospitals, industrial instruments and a host of other occupations. Many of these radioisotopes have long half-lives creating the need for safe disposal. Others are excreted from hospital patients or disposed of in small quantities in the disposal system either intentionally or accidentally. Accumulation in the common input conduit of a sewage plant creates a potential safety hazard. Diffusion through common soils may cause contamination to our natural water resources. There is, therefore, an ever increasing need for continuous monitoring of the effluent from hospitals, laboratories, nuclear reactor sites, as well as the influent to the sewage disposal system. The monitoring system could be set up to sound an alarm when the radiation levels become greater than established safe levels.

The Industrial Nucleonics Corporation manufactures a continuously level measuring system which is composed of a detector, amplifier and radioactive source units. The detector contains Geiger Mueller tubes which feed pulses into the amplifier unit, which in turn registers its output on an indicating meter or recorder.

Normally the source unit is mounted on one side of the vessel with the detector on the other. The detector operates on the amount of gamma radiation transmitted over the top of a liquid or solid contained in the vessel.

Although alpha and beta particles may also make up a portion of the contamination in any stream, it is felt that the gamma radiation hazards alone or combined with one or both of these requires monitoring. Any alpha or beta detection device will, because of the low penetration ability of these particles, be necessarily fragile in design. The ruggedness of the AccuRay detector makes it ideally suited for the application of monitoring gamma radiation in waste streams. The construction of the equipment is illustrated in Figure 72.

CONSTRUCTION OF INSTRUMENT

The Geiger Mueller tubes are mounted on an aluminum I-frame enclosed in a schedule 40, 3" pipe section. The end caps and condulet may be sealed water tight making the unit perfectly suitable for stream environments. The unit may be made as long as desirable

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* Presented by D. K. Eichner, Product Manager, Industrial Nucleonics Corporation.

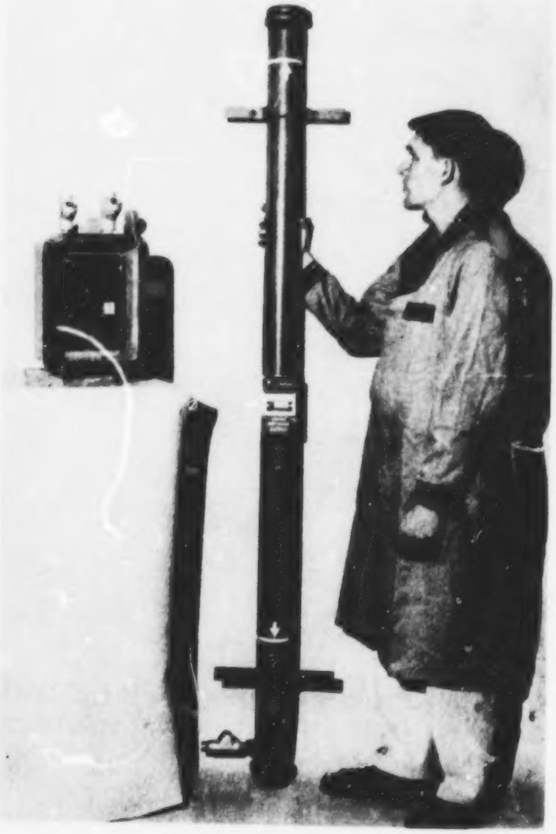

Figure 72. THE ACCURAY DETECTOR.

for averaging radioactivity throughout considerable depths or short for shallow measurements. The detector is normally supplied with a single set of electrically paralleled Geiger Mueller tubes. If more sensitivity is desired, four or more Geiger Mueller tubes can be geometrically and electrically paralleled with the normal single set. The amplifier is comprised of solid state devices, is enclosed in an explosion-proof housing and is essentially maintenance free. The output may be fed into a 0 to 100 microampere meter or a -10 to 0 millivolt recorder.

The pulses or counts from the detector are coupled through a blocking capacitor into a common collector transistor. Biasing on the input stage of this transistor serves to equalize the various pulse heights received from the detector unit. The resulting pulses are coupled through a capacitor into the base of the transistorized multivibrator section. Each pulse received at this point is used to "trigger" the multivibrator section, which in turn produces a uniformly-shaped pulse at its output. These pulses are coupled into an integrating circuit so as to give a signal voltage related to the number of pulses received per interval of time. The duration of these are uniformly determined by the pulse width control and is adjustable from about 60 to 250 microseconds. This is accomplished by changing the feedback capacitance in the multivibrator circuit.

Any background radiation is bucked out with a power supply voltage of opposite polarity to the voltage developed as a result of this radiation being detected. The highest sensitivity of the system is obtained with the largest pulse width permissible.

EXPERIMENTAL DETAILS

The AccuRay detector was supported in a 55-gallon drum with the active section of the unit completely submerged under water, as shown in Figure 73. The output of the amplifier was fed into a Minneapolis-Honeywell 10 Mv. recorder. Knowing the volume of the drum, the activity of the I-131 and weight of radioisotope placed in the drum, the activity per milliliter could be calculated. Various concentrations of I-131 in the form of sodium iodide were dissolved in the water and the recorder readings plotted against concentration. This is shown plotted in Figure 74.

The pulse width of the amplifier was set at 250 microseconds giving a non-linear trace at the higher concentration of radioisotope due to amplifier saturation. Calibration was throughout the range of 6×10^{-5} to 1.4×10^{-3} microcuries per milliliter. Prior to calibration, the recorder was set for maximum sensitivity with an arbitrary zero-point at 0.11 on the recorder scale.

Iodine-131 was used in the calibration because it is the isotope in most frequent use in the hospital. It was felt there is more likelihood of I-131 being involved in any large spill into the sewer system than any other isotopes. The calculated concentration of I-131 was compared to measured activity. This was

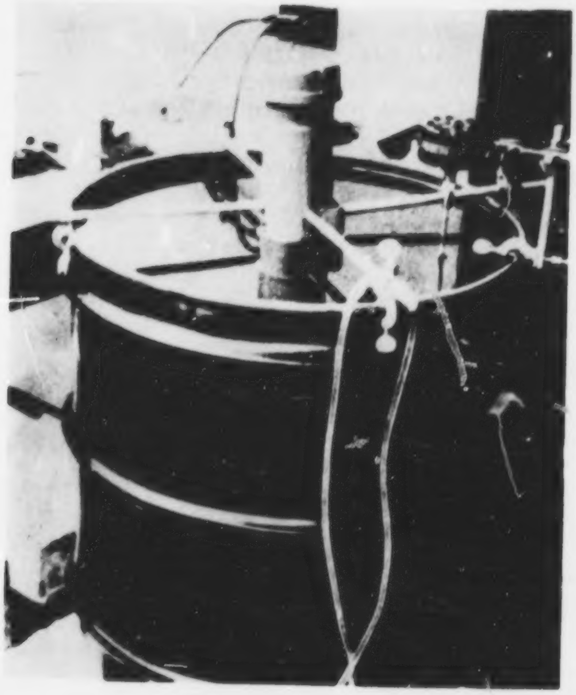

Figure 73. THE DETECTOR MOUNTED IN A STEEL DRUM.

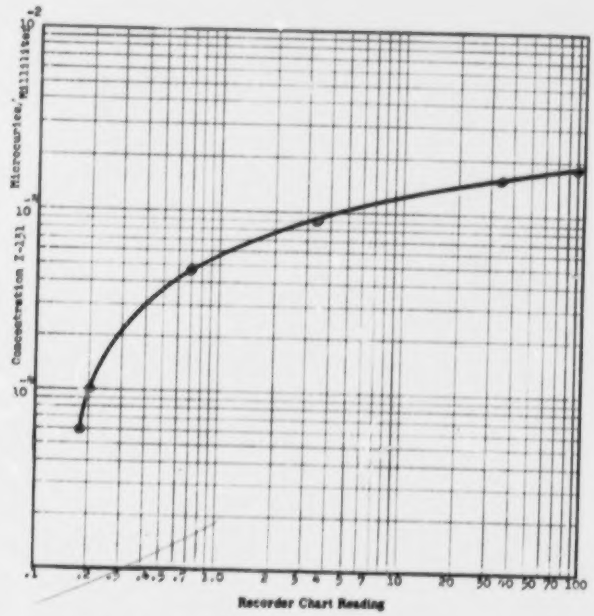

Figure 74. CALIBRATION CURVE OF I^{131} CONCENTRATION VS. RECORDER READING.

done at a time when the total amount of I-131 (corrected for decay) was 301.74 microcuries, which is equivalent to 1.435×10^{-3} microcuries per milliliter in the drum. Four one-milliliter samples were collected at various depths and distances from the center of the drum. These were counted in the well type scintillation counter at the University Hospital Radioisotope Unit, which had previously been calibrated for Iodine-131. The average measured concentration was 1.415×10^{-3} microcuries per milliliter, a remarkably close value to the calculated value. This concentration was then diluted through the calibration range.

It was desirable to measure the total amount of radioisotope carried into the Ann Arbor Sewage System. Robert J. Augustine published a report on "The Disposal of Radioactive Wastes from the University of Michigan Hospital to the Municipal Sewage System". He found that a slug of I-131 flushed down the toilet located on the first floor of the hospital would appear in the sewage treatment plant influent in about 115 minutes when the flow was 9.5 million gallons per day. The dilution factor obtained was about 1×10^5 for the peak concentration. It was also found that 98.1% of the activity released at the hospital would appear in the influent at the sewage treatment plant. This figure was used in latter calculations from peak values of amounts of isotope released to the stream.

SEWAGE DISPOSAL STREAM MEASUREMENT

After the unit was calibrated in the laboratory, it was removed for application to the influent stream of the Ann Arbor Sewage Disposal Plant. This application is shown in Figure 75. Since it was desired to measure the lowest possible concentration of I-131 in the sewage stream, the laboratory settings on the instruments were used in this experimental set-up.

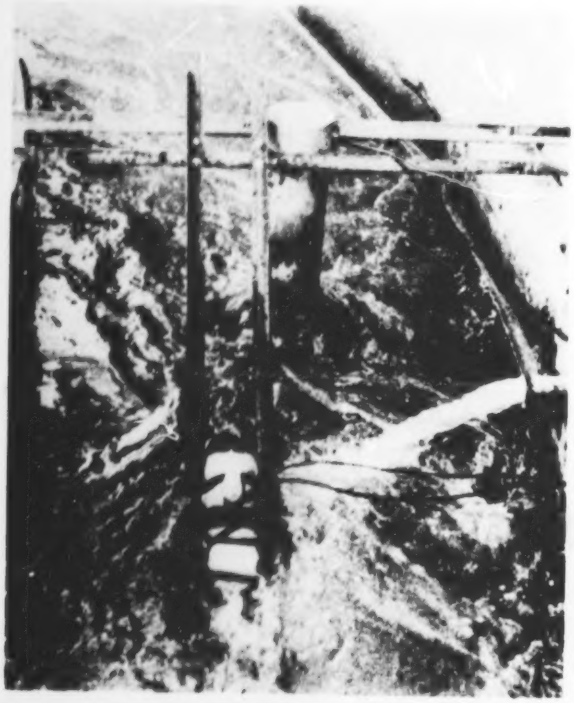

Figure 75. DETECTOR MOUNTED IN A SEWAGE TREATMENT PLANT INLET.

The detector unit was immersed in the influent channel of the plant next to the existing ionization chamber. The recorder was set-up in a temporary location in the basement garage of the plant.

Various amounts of I^{131} contained in urine collected from patients who had received "Therapy B" treatments (100-250 mc radioiodine) were introduced into the sewer system from the University of Michigan Hospital. Introduction was accomplished by passing the urine into a toilet and flushing five or six times to send the iodine into the system as a slug.

Over a period of several days, (May 12 to 26 inclusive), several points were obtained as plotted on Figure 76. The amount of I-131 available was determined by the number of patients given "therapy B" treatment.

As an example of the observation, on May 20, 1960, 36 mc. of I-131 in 500 milliliters of urine was flushed into the sewer from the toilet on the 7th floor of the University of Michigan Hospital. Grab samples were collected at the sewage plant as the I-131 passed the monitor. One milliliter aliquotes were then pipetted from the sampling bottles into a test tube and counted in the well-type scintillation counter (Nuclear Chicago Model 183 scaler) in the Radioisotope Unit at the University of Michigan Hospital. The concentration of I-131 in one milliliter of sewage influent versus the time after entry at the hospital is shown in Figure 77.

The peak determined from the grab samples was 1.80×10^{-4} microcuries per milliliter at 120.5 minutes after entry into the sewer system at the hospital. This is compared to the observed peak of 0.25 on the recorder scale representing a concentration of 2.3×10^{-4} microcuries per milliliter as shown in Figure 74. Since the initial amount of isotope was 36 millicuries in 500 milliliters, the concentration was 72 microcuries per milliliter. Dividing this by Augustine's dilution factor of 1×10^{5}, a concentration of 7.2×10^{-4} microcuries per milliliter is obtained. This is 3 to 4 times larger than actually observed, but in excellent agreement, considering the techniques used.

CONCLUSIONS

The University Radiation Control Service maintains a continuous monitor in the influent channel at the Ann Arbor Sewage Treatment Plant. An ionization chamber connected to a suitable amplifier and recorder is employed for this measurement. Because of breakdowns, this system is seldom operable more than a few weeks at a time.

It appears that the simple, suggested industrial type Geiger Mueller detector system will provide satisfactory monitoring. The results obtained by the AccuRay system are encouraging. Throughout the entire laboratory calibration and field trial, the instrument was in continuous operation without any breakdown.

The system is sensitive to low levels of radiation. Its linear output versus counts makes it difficult to measure high radiation levels because the indicator may be beyond its limits

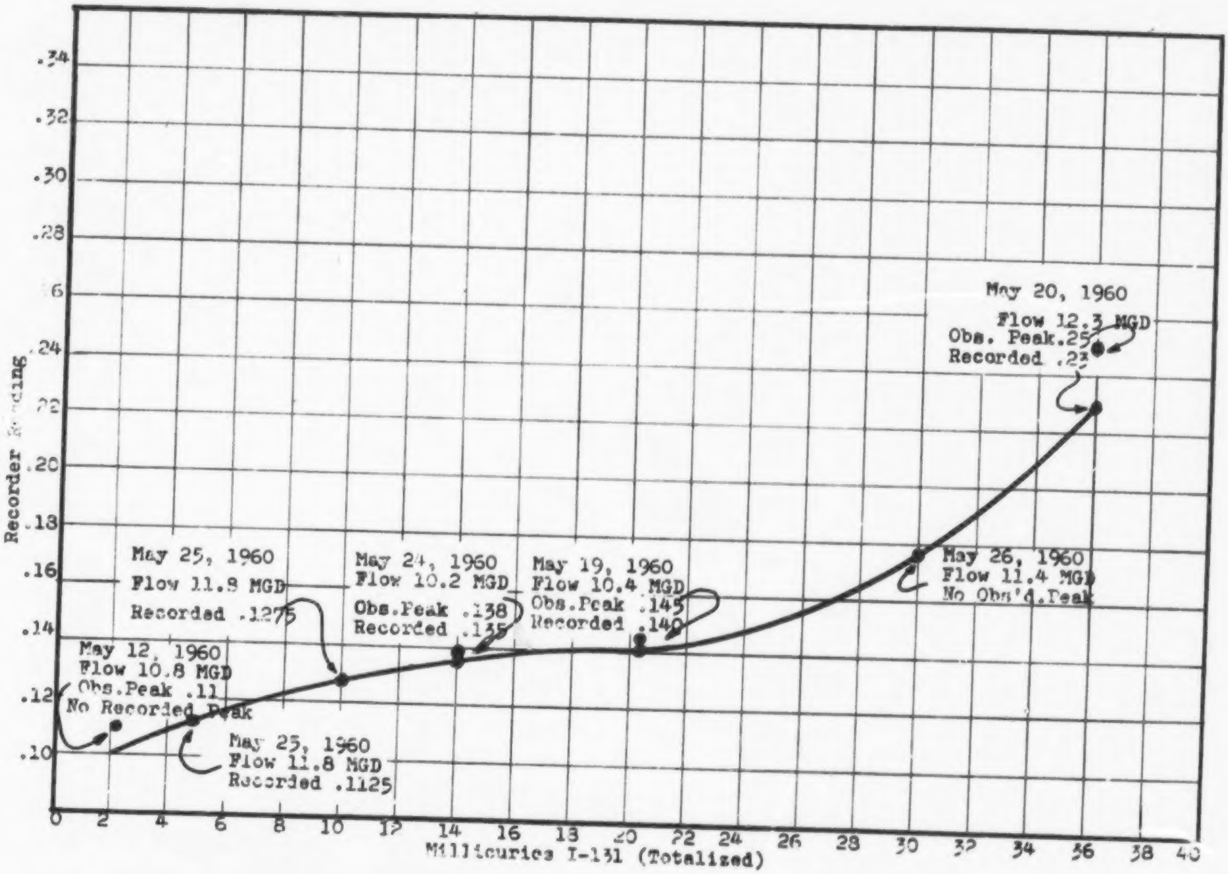

Figure 76. PEAK READING ON RECORDED VS. ACTUAL AMOUNT OF I^{131} CONTINUED IN SAMPLE DUMPED FROM UNIVERSITY HOSPITAL.

of measurements. A logarithmic indicator output system would be more desirable in this case. The detector unit could be made even more sensitive by encasing in thin walled metal tubing rather than schedule 40 pipe, but some of the ruggedness would be sacrificed.

It is usually required that contamination of streams by I-131 be below 9 X 10^{-5} microcuries per milliliter when leaving a controlled stream to enter a river, lake or similar water system. Contamination from I-131 below 3 X 10^{-6} is required when the water is to be used for human consumption. The AccuRay system as installed in this preliminary investigation was sufficiently sensitive for the former application, but not for the latter. It is believed that with the refinements suggested, even this latter requirement may be easily obtainable.

It would appear that this simple, rugged system would be suitable to measurement of surface waters for radioactivity. Interest is rapidly growing in routine monitoring of such waters with the development of nuclear power reactors and other peacetime atomic energy uses. State and interstate agencies, as well as municipalities are becoming increasingly concerned about establishing such programs.

Such inexpensive rugged equipment may soon be installed in the effluent from most laboratories, hospitals and atomic energy

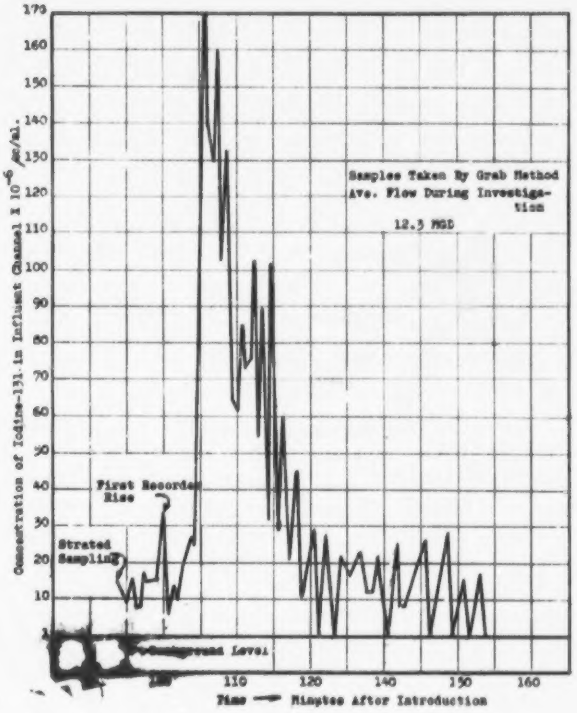

Figure 77. CONCENTRATION OF I^{131} VS. TIME OF ARRIVAL.

installations to monitor contamination at these points of entry. It will most likely be some time before alpha and beta monitoring equipment is designed with equal ruggedness for similar applications.

FUTURE CONSIDERATIONS

Certainly radioactive contamination monitoring is required for good quality water production but the whole field of analytical instrumentation as applied to this field is in its infancy. Many of the routine laboratory measurements could be made continuous. Stream odors lend themselves to Chromatographic analysis. Biological oxygen demand, chemical oxygen demand and dissolved oxygen already are being monitored continuously. Conductivity and pH measurements are well known.

The real future challenge is to measure bacterial content on a continuous basis. Techniques used in bacteriological warfare monitoring devices might be adaptable. Multichannel elemental analysis could possibly be accomplished by X-ray emission or neutron activation analysis.

An intensive study program of good water quality parameters is needed to establish criteria for such measurements. The Ohio Symposium on Water Quality Measurement and Instrumentation is an ideal group to assist in establishing this goal.

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WATER, A GLASSFUL, A LAKEFUL -- THE INSTRUMENT APPROACH

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The old adage, "You don't miss the water 'til the well runs dry," is coming closer to home than most of us would like to feel.

It is strange in this world of advances that we should find a condition developing that could so grossly affect our prosperity and security as the condition of our water supply. Water is a natural resource which, thanks to Mother Nature, is kept in a quantity balance the year 'round. Exploitation of this resource has seriously affected the available supply by pollution and mismanagement.

Water as a chemical is as old as the hills. It hasn't had a change in make-up -- no design requirements are necessary to improve its value. Generally speaking, if found in a virgin state, it makes a wholly acceptable raw material. What, then, has happened? Practically speaking, water is indestructible. And no matter how hard we try, we end up with the formula H_2O. However, we have had considerable success in supplementing this H_2O with additions of organic and inorganic pollutants to the extent that this previously acceptable chemical is now productwise unacceptable for consumption. We now realize this fact. Fortunately, looking at Mother Nature again, we're having the opportunity of doing something to bring back the quality and quantity of our water and relieve the situation.

Rather than speak in such generalities, there are frequent situations where the demand for water exceeds the present local supply. This situation falls in with the considerations we will discuss later.

Were it not for the dedication of a small group of individuals who have been active for many years advancing the technology of water supply, this meeting today would not have been possible. It is through their efforts that we are meeting to discuss the advances made and the things to come to preserve our most basic and vital raw material -- water.

It is a comforting thought to turn a valve in a water line and be assured of the results. We take for granted that (1) water is there and (2) it's unquestionably fit for the use we've planned. Too often, though, these conditions are not assured. We might cross our fingers but who's kidding whom? We've progressed beyond the stages of hexes and superstitions. We have a planned economy and, with our anticipated population and industrial increases, this planning will have to attain a finiteness that will assure all concerned that the situation is well in hand.

I've chosen the topic, "Water, a Glassful, a Lakeful -- the Instrument Approach," because I feel it fully expresses the magnitude of our problem. Technological advances in the field of water resources in the past forty years have been nothing to be proud of. They surely are inadequate to cope with present problems and are definitely sadly lacking for those that we will meet shortly. It is no longer a problem for the relatively few specialists in the field to correct, but rather a challenge for society and industry to cope with. In short, the requirements of this field are so broad that everyone who pulls a chain or depresses a lever should stop and consider the ramifications.

The general public is waking up to the fact that something is not good. Whether it be a foul taste in a glass of water, a "No Swimming" sign on a once beautiful beach, or a lawn sprinkler that won't oscillate due to low line pressure --- the general public is aware of the problem. And it is from this source that the money to finance improvements comes. This could be in the form of increased water rates, higher taxes, or higher prices for commodities. An economic justification has been established.

The instrument approach to a problem tells us the quantity and quality of the product. It enables us to plan an action and account for the success of this action. Instruments are our guardians. But where are they?

With little exception, our water is being controlled by outdated equipment borrowed from the chemical process industries and adapted for use. Our product is still largely controlled by the laborious, time-consuming, wet laboratory procedures worked in thousands of laboratories throughout the country. Too often the information received is academic -- we know what happened before -- but we should know what is happening now. Unfortunately, little is available to tell us this.

Consider for a moment an ideal situation -- a river on which are located industrial operations and cities. The industrial plants are using water and discharging water, and the cities are doing the same. Assume the supply is quantitatively adequate. It is of general concern that the water is qualitatively adequate. To insure that the water is of good quality, a series of monitors are installed at strategic locations on the river. These monitors are part of a network that supervises the whole picture. This affords a program of general and specific information for all interested parties. Inadvertent discharges can be accounted for, and assuming that everyone is conservation conscious, we have the situation well in hand. The industrial operation will know that it is losing a product and the water treatment plant will immediately know the condition of its intake water. This situation is not reserved for the large cities and plants but is in order for every common water user.

Just how good is a system of this type in operation? With very few exceptions, there is no system. The underlying cause for this inadequacy is that equipment is either undeveloped or overpriced. I don't like to use the word "cost" at the same time the word "need" is used, but economic justification quite often determines an action -- we do live in a relatively free-economy nation.

The era is here wherein specific local accounting is in order for our water supplies. Methods and procedures put in force five or ten years ago are completely inadequate to cope with this situation. Quite often, too, that new treatment system installed last year in accordance with old specifications is but a futile gesture.

I wish I had a little black box next to me here that would answer our problem -- a device that would watch over our water supplies constantly and tell us of the immediate conditions at a location. This desire is in accord with our needs for the rapid determination of all variables concerned with our water supply.

However, this picture does not have to appear very dark -- a great deal of advance is being made in our research laboratories to build for this newly rejuvenated industry devices to bring its technological status up to the present economic needs. Unfortunately, it's taken quite awhile but now the justification is more apparent.

A great deal of the equipment required will come from the manufacturers of instruments. These devices will be rugged, compact, and self-sufficient. Due to the great numbers involved, their cost will be moderate. They will be inconspicuous to reduce pilferage.

The instruments will be widely distributed, enabling network integration. The network will encompass the entire country, disseminating that information which is pertinent to local and governmental agencies who then can control the entire picture.

I do not want to imply that the control picture is as simple as a black box affair. We still will want to know specifically a condition to permit interpretative operations -- or just how to alleviate a condition when it is at hand. Any supplementation to the existing methods of analysis would be invaluable. However, the widespread implications of water demand accurate, immediate control that only continuous instrumentation can afford.

I recently made a national survey of water, sewage and industrial plants -- talking with operators and officials at great depth -- and it was most gratifying to learn of the individual efforts of these people in improving the quality of their product and the efficiency of their processes. When a water plant operator speaks with pride of the quality of his product and an industrial operator speaks with pride of the quality of his advances to keep his waste from contaminating our streams, we know that we are on the right track for the future. These people require the proper tools for the job at hand and for the future. It is a challenge for the manufacturers of instruments to develop these tools.

Advances to date in the field of water instrumentation have been nominal, but I speak with conviction when I say that the day is not far off when these challenges can be met with proper devices for the task at hand. Instruments are needed to continuously and economically measure pH, B.O.D., C.O.D., D.O., sediments, conductivity, color, turbidity, stream flows, radioactivity, level, coliforms, evaporation, transpiration, oil films, taste, odor, organic content, specific chemical concentrations, etc.

Not to slight those producers of equipment on the market presently and doing a fine job, let me say that the ultimate high quality, moderate cost device is still desired. This is a challenge for the industry.

Considerable success has resulted in many of these devices wherein the wet laboratory analysis has been automated, short of putting a chemist in a box. However, this is not the end result -- not the black box that is needed. It is the aim of the instrument industry to relieve the little man with the sampler and pipette of his task and allow him to spend his time in improving operations with these "ultimate" devices which will produce a better product at possibly a smaller unit cost.

Perhaps I should get off Cloud 9 for a minute and get back to earth. Our future problems are with us today. The immediate solution is to utilize that which we have presently as stopgap aid, relieving those problems with the best equipment that is available. As new equipment is made available, it should be used to replace or supplement existing systems.

The optimum device is one that measures all variables without making contact with the medium. It is completely portable and self-powered. Its price is under a thousand dollars. It's a shame I don't have a few here for I'm sure there's some demand.

Maybe this optimum device is somewhat removed from practical reality -- it has its advantages, though, and after evaluating its character you will see some philosophies that are not too far-fetched.

Let us look at the universality of detection. We all realize that there are some key analyses that tell us the general acceptability of water. Then, too, these analyses by today's procedures can be made using non-contacting means. Portability is not beyond practical design concepts. Finally, price -- obviously, if enough units are sold, low price is not a difficult goal.

This black box I've described to you can't replace the chemist. Decisions arising from instrumental analysis will still be governed by the experience of our operators. Some samples will still be needed to permit those determinations necessary to fill in the analytical picture. However, the frequency and extensiveness of today's procedures can be radically modified.

I've made several references to price along the way, and I'd like to expand somewhat on the topic of price, along with quality and design. While we're inaugurating a new device and a new concept, let us go a bit further and clean our slate somewhat to open our minds to new principles of design. After all, if the equipment is for a specific field it should cater to that field.

The criteria governing the production of this equipment should be headed by quality. Too often the trend will be to cut corners to save a few pennies -- pennies which will be repaid many times had they not been deducted. I'm not implying that we should all trade in our flivvers and buy Cadillacs, a gold-plated type installation will never support economic justification; however, the demand requirements of this field should justify high quality.

It is desirable, when a water instrumentation program be designed, that a flexibility factor be included. This factor permits that expansion necessary to cope with inevitable growth and enables the system to grow with demand and technology. We find today that those systems recently built or under construction will fall short of the demands we will encounter in ten years. With increasing water usage it is obvious that an integration of water systems or cooperatives will be formed and those networks of control and supply will expand until geographical cross-linking will be commonplace. Actually, this trend is well underway.

Automatic programming will be mandatory. Supervision of control and distribution will have to be spontaneous. The scope of data acquisition will require responses only possible through analytical computer systems.

Travel with me now to the community, "Your Town, U.S.A." "Your Town" has a water supply and waste disposal system drawn from and discharged to "Clear Creek." When "Your Town" was planned, ample capacity was provided to enable reasonable expansion in its water supply. Waste disposal was no problem since it was fairly isolated. However, with suburban and industrial growth we now find this once fairly isolated community a part of a metropolitan combine. In order to exist effectively, "Your Town" now has to integrate its water and waste operations with a cooperative system complex. No longer can the routine operations, once considered adequate, cope with the everchanging conditions of a multisystem program. One community cannot function without regard for its neighbors. Before any operational changes either in water demand or waste disposal can be made, the effect on the complete system must be considered. The only possible solution to cope with all the ramifications of a cooperative system is through automatic data accumulation and computation.

The ideal situation would be to have "Your Town's" system integration accomplished with the network with simple tie-ins from existing equipment. This unfortunately is not the case here since the majority of instrument devices in water use today are of older types; consequently, "Your Town" will require transducers or converters up to the total replacement of all pertinent controllers and receivers before the integration is possible.

The area we're meeting in today is proceeding with an integrated network development that will minimize the pitfalls of inadequate planning. When the system is completed, the Ohio River Valley will have one of the most complete control complexes in existence, a model from which other areas can profit. It will have strategically located monitor stations connected to a central data logging system. This complex will enable constant supervision over a large, highly industrialized area.

The ultimate in a system planned in this manner is the addition of automatic supervisory control to designate area action where required.

A program of the type we have just looked into can be a successful reality only through the joint efforts of producers and consumers. Without the demand for improved technology and quality in components, instrument manufacturers will have no alternative but to produce nominal average gear. The consumer has to supply the stimulus.

We in the manufacturing end are working our ouija boards daily to develop designs and systems we hope will be what is desired and used in the near future, but unless we're all in line with our thinking, the success of these prodigious plans will never be realized.

I should like at this point to discuss a system ideally designed for the supervisory control of a water and waste complex. In keeping with the plan of potential growth, it has flexibility factors. The ultimate system may be acquired gradually in stages as the need arises. It is versatile and, lastly, it has high quality.

Exactly what is a system of this type composed of? At an initial glance the devices shown here as a composite package are a normal instrument system (Figure 78). What is not shown in detail is the compatibility of components. Components of systems are employed to greatest advantage when their lineage is along common lines, or to express this genetically, members of the same family. When this is factual, those finite considerations that are included in the design and development of equipment will enable the user to reap maximum advantage from his system.

Using a system such as this, variables are detected, fed through transducers to match signal type, and are connected to an automatic selector switch. At the start of each cycle a signal of fixed value is automatically fed to a digital potentiometer, measured and printed as a check on system operation and accuracy.

Energized by a digital clock, a programmer starts the automatic selector switch. As the switch steps through each point to be measured, the input variable is automatically adjusted for range, span and zero suppression,

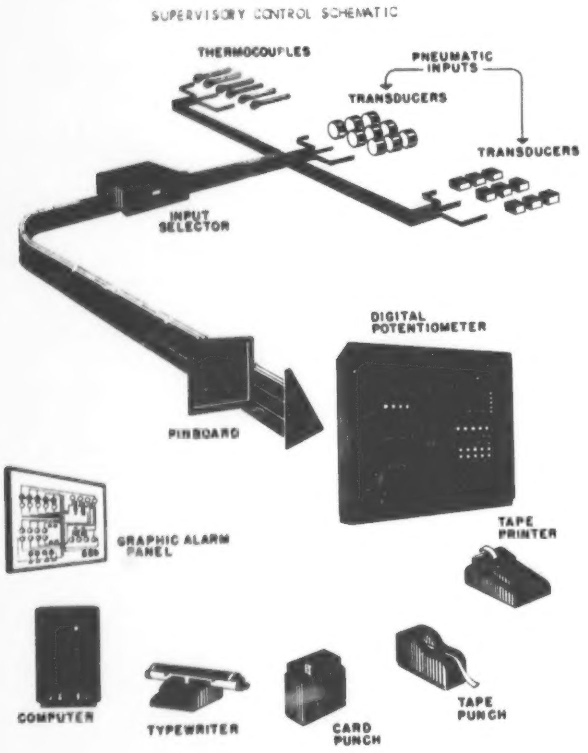

Figure 78. SUPERVISORY CONTROL SCHEMATIC

then transmitted for measurement and digitizing to the digital potentiometer.

The measured output is logged in a suitable manner or fed to a computer which analyzes the signal for proper response action which can be retransmitted as a supervisory impulse for corrective action if necessary.

Any number of options can be selected. An off-normal point, high or low, can be printed in red and/or alarms sounded with visual identification. Between automatic cycles the operator can manually select points, or a demand logging cycle can be initiated, or the instrument can be set to scan off-normal points at a rate of 4 to 8 points per second.

Systems can be made larger in multiples of 40 selected inputs, providing the necessary flexibility. Cycles can be automatically set for periods of 1, 2, 5, 10, 15, 30 or 60 minutes.

Within the system the operator can change the logging or scanning sequence at will, substitute one type of input for another, add inputs easily, expand the number of measuring circuits and, if desired, can apply the system to a completely different process. All these features are performed with an accuracy of ±0.1% of reading.

Transmission of signals from one point to another can be handled over any commercially available channel facility, including private wires, telegraph or telephone circuits, microwave, UHF, VHF and carrier current.

The ideal system should have an ideal brain. A computer is available, designed for industrial operations, and is the keystone of good supervisory control. It is digital and operates with computations that are based on currently sampled values of operating data. This produces answers in time for control action at speeds such as 8000 additions, 1250 multiplications or 400 square root extractions per second. Memory is supplied with the speed of a magnetic core and the permanence of a drum.

Response is in the form of punched paper tape, output signal for action and control and visual annunciation.

Finally, this computer is compatible with all existing pneumatic and electrical instrumentation through the flexibility of peripheral equipment.

An instrument supplier is very much like a bank. In this bank are stored a collection of devices to be drawn from to build an instrument system (Figure 79). The effectiveness of this bank can only be seen when it is put to test. When sufficient compatible devices are contained to meet every challenge put to it, then you would consider it a very good bank. If the banker goes further and supplies technical service, say, in the form of engineering, installation and maintenance, then the picture looks even better. Consequently, one should choose his instrument supplier as carefully as each of us personally chooses his bank.

In designing a system to control a water and waste network, we take compatible integral components and build them into a complex to perform the function necessary today, with a thought to tomorrow.

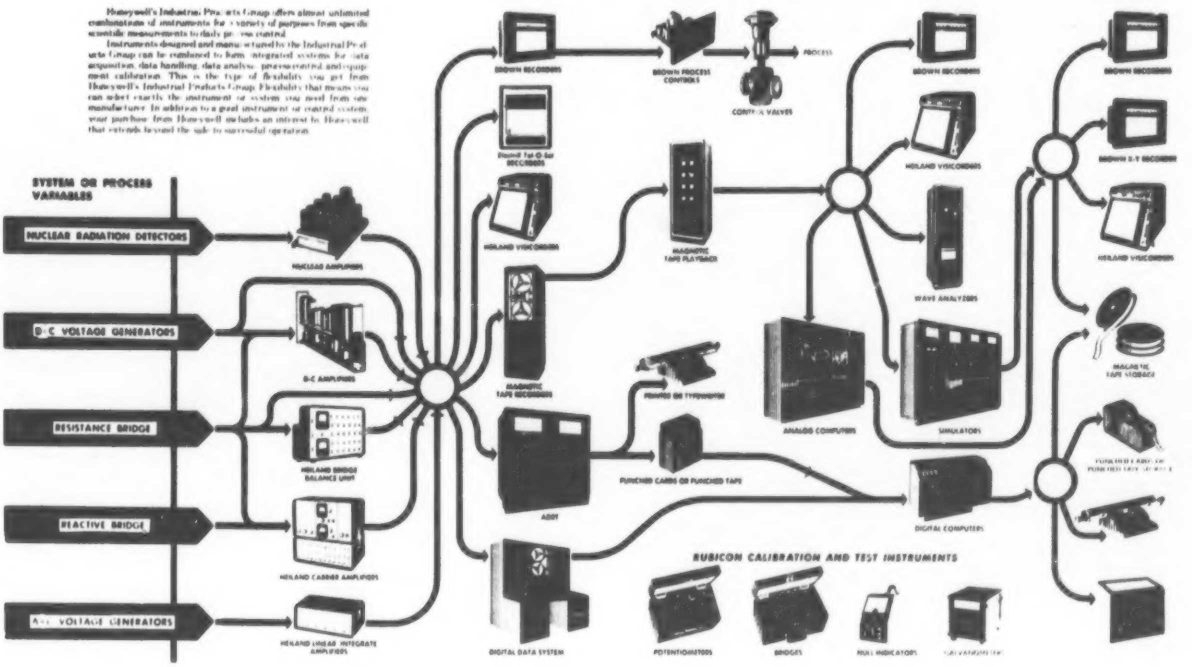
SYSTEM OR PROCESS VARIABLES
NUCLEAR RADIATION DETECTORS
D-C VOLTAGE GENERATORS
RESISTANCE BRIDGE
REACTIVE BRIDGE
A-C VOLTAGE GENERATORS
NUCLEAR AMPLIFIERS
D-C AMPLIFIERS
HEILAND BRIDGE BALANCE UNIT
HEILAND CARRIER AMPLIFIERS
HEILAND LINEAR INTEGRATE AMPLIFIERS
BROWN RECORDERS
Electronik Tel-O-Set RECORDERS
HEILAND VISICORDERS
MAGNETIC TAPE RECORDERS
DIGITAL DATA SYSTEM
BROWN PROCESS CONTROLS
CONTROL VALVES
PROCESS
MAGNETIC TAPE PLAYBACK
PRINTER OR TYPEWRITER
PUNCHED CARDS OR PUNCHED TAPE
BROWN RECORDERS
HEILAND VISICORDERS
WAVE ANALYZERS
ANALOG COMPUTERS
SIMULATORS
DIGITAL COMPUTERS
RUBICON CALIBRATION AND TEST INSTRUMENTS
POTENTIOMETERS
BRIDGES
NULL INDICATORS
GALVANOMETERS
BROWN RECORDERS
BROWN X-Y RECORDER
HEILAND VISICORDERS
MAGNETIC TAPE STORAGE
PUNCHED CARD OR PUNCHED TAPE STORAGE

Figure 79. AN INSTRUMENT BANK COMPOSITE

The growth situation I've been discussing is boiled down to numbers and neatly defined by the Bureau of the Budget as a Standard Metropolitan Statistical Area. Today there are approximately 200 SMSA. By the year 2000 there will be 300. The average area has a population upwards of at least 50,000 inhabitants. The growth concept of these areas is so rapid that statistics are normally out of date at printing.

With this type of growth to cope with, technology enhancing the science of water supply must advance at an accelerated rate. Through the apparent lack of interest on the parts of users and suppliers associated with this field, we have coasted along for the past 60 to 80 years with little concern for the future.

Instrument manufacturers are not wholly to blame for the lack of advanced devices, and instrument users are not wholly to blame. However, at this point results are needed and immediately. Normally a period of two years is considered for the presentation of a device or system for our markets. Unfortunately, we no longer have normal timing available -- population and industrial requirements grow exponentially. This is a real challenge.

To accomplish this task using universal equipment is, as we now see, an impossibility. Standard gear, we must realize, is inadequate -- is no longer acceptable as a standard. Our design requirements must be reevaluated. Using that operational data collected over the years, a relationship between variables must be found which would enable a simplification of the analytical requirements. Hence the determination of an outside effect would be sufficient to allow the logical determination of the cause.

Unfortunately, too, this thinking will settle only those problems that have been with us on a smaller scale. We are now faced with the products of our advanced technology. We are faced with the problems of determining pollutants that were unknown ten years ago.

Concentrations of heavy metals are increasing, exotic organic chemicals are becoming commonplace, and the presence of materials which defy settling in our streams is increasing at an alarming rate. I'm sure we don't have to look about a great deal for an inspiring challenge.

There is a solution to this problem. In essence, the answer is application of known procedures to variable determinations. This is perhaps an oversimplification; however, an unbiased summary of known techniques will turn up a great many solutions to our problems.

Once we have established our course -- the only conceivable response is action. Instruments and systems must be born from the research specialists' discoveries and converted to production type devices based on continuous operation concepts.

The measurement of variables in a water medium cannot be prorated from chemical process instrument design. In a chemical plant stream the variable detected is often the only component of the stream that exhibits a change. The properties of the carrier stream are nominally constant or, in exception, will vary in one component other than the sought-for unknown.

In water analysis we are confronted with one of the most dynamic samples imaginable. Here we have a mixture of organic and inorganic chemicals, plant and animal life all thrown together with silts and suspended solids.

Too often the success of analysis of one variable hinges on the presence or absence of another. In designing a device, therefore, there are several approaches. The variable could be removed from the stream and measured directly or by difference. The variable could be measured directly in the stream. The variable could be combined in the stream with an additive, the consumption of which is an indication of the variable amount. And so on. There is no rule of thumb -- no preset way. The field is open to ingenious development.

The field of originality is by no means confined to quality methodology. The question, "How much?" has to be answered with equal import as the question, "How pure?" Here again we are dealing with problems that have never had optimum answers. Measuring flows in pipes and troughs is no great chore but when flow determinations are required in channels such as streams and rivers, where variable cross-section is encountered, the problem once again takes on dynamic aspects.

To date we've contented ourselves with relative results derived from averaged approximates. When one considers that in less than ten years our potential rainfall will equal our estimated water consumption, accurate accounting of all water flows is definitely required. Whether it be for the irrigator or the industrial plant, water allocation must be based on sound measurement.

At present, the academics of water supply are suffering from the lack of proper flow and level data. From these data the future in water supply must be planned. The gravity of these measurements can be seen if we realize the plight of a farmer, who has a planned water economy, not having previously committed water near the end of a crop cycle when he needs it, or a community having to transport water to exist. Measurement will not produce water that isn't there, but it will enable sound planning to insure equitable distribution and facilitate the acquisition of alternate sources of supply in advance of need.

The science of instrument application can only benefit the field of water supply. It enables the answers to the questions, "How much? How pure?" to be arrived at accurately, conveniently, and economically. Through instrumentation the field of water supply will move up to a level with the other process industries, producing an assured product at no economic hardship.

ANALYTICAL MEASUREMENTS FOR CONTINUOUS TRANSMISSION

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In water quality instrumentation when measurements are to be transmitted, it is not enough to select the variable to be measured simply on the basis of whether it can be measured or not. There are other pertinent factors to be considered, such as the personnel attending the installation, the frequency with which the instruments are inspected and other characteristics of the instrumentation location.

Many measurements which are practical in a laboratory setup or at a continuously attended station become nearly impossible on a continuously unattended basis. Measurements involving elaborate sampling, purging, titration, and so forth, cannot at the present state of the art be considered practical for continuous measurement and transmission.

It may seem surprising that the representative of a major instrument company should express this viewpoint. However, a careful and realistic consideration of water treatment instrumentation shows clearly that many of the analytical measurements we have today, if transferred to a continuous basis, would definitely fall into the area of laboratory gadgets, rather than tried, tested and reliable measuring systems. There is no doubt that if sufficient money and effort were put into any measurement development, it could be perfected. There is, however, some question in our mind, in light of the measurements which can be made with good reliability, whether such an outlay would be justified for measuring many variables.

Let us break down those continuous measurements which are to be transmitted on the basis of the degree of attendance of each at the water quality stations. Such a classification might be as follows:

CLASS A -- Frequenty Inspected - Stand-by Power Supply

ANALYTICAL MEASUREMENTS

Temperature
Conductivity
pH
Dissolved Oxygen
Turbidity
Chlorine Demand

CLASS B -- Infrequently Inspected - No Stand-by Power Supply

ANALYTICAL MEASUREMENTS

Temperature
Conductivity
pH

Here the Class A station is inspected frequently and is provided with stand-by power facilities. These stations would obviously be located at the most critical locations in any water quality network. Class B stations are those which would be expected to operate with infrequent inspection and the loss of their measurements due to power failure for short periods of time would not seriously upset the efficiency of the entire network.

Let us examine the type of measurements, both mechanical and electronic, included in Class A stations. Measurements requiring sample systems are, of necessity, limited to this class of station. Routine inspection at the rate of once a week should be conducted and provision might be made for a central alarm system to indicate the failure of any measurement so that repairs could be made at once. Stand-by automatic power facilities, similar to those furnished at present by the telephone companies should be available.

The Class B stations would include only mechanical and simple electronic measuring, such as for pH and conductivity. We would not recommend including any measurements which require sampling systems, since the addition of sampling greatly reduces the reliability of any measurement system. Inspection could be as infrequent as once a month, and no stand-by power would be necessary to fill in for brief temporary power failures.

In view of the number of papers which are being presented throughout the country on water pollution and considering the extremely detailed nature of most of them, we are all in danger of becoming so embroiled in detail that we forget the basic problems.

We need to step back from the details and keep in mind that the basic problems are these:

1. Is the water dangerously polluted?

2. Can we find what is causing it and eliminate the cause?

3. Can we erase the pollution by treating the water?

The third question is beyond the scope of this paper and deserves special treatment elsewhere.

When the analytical chemist enters the water quality field to answer the first question, he soon discovers that his basic requirements are a good nose, good eyes, and a fish. He must use his nose to see if the water smells bad and his eyes to see if the water looks bad and if the fish is alive or dead.

This is said very seriously, because these are the real reasons why we are concerned with pollution.

If the water smells bad, it leads people to believe that it is a health hazard, whether it is or not. If the water looks bad, their aesthetic senses are wounded, and they are sure that something should be done about it. And if the fish dies, we all fear that people could also die from drinking the water.

Just as the electronic computer people have determined that it would take a fabulous sum of money to duplicate the human brain, so much so that it is not practical to shoot for 100 percent duplication, so, too, we realize that it is not economical to try to duplicate the human eye, the nose and the fish.

Nevertheless, the computer people continue to build computers which are something less than 100 percent duplication of the human brain, and they build them because they do some things very well and are economical. They still have some questions as to how far they should go in development but they are, of course, well advanced.

Automation in the water pollution field has a long way to go in comparison with the process industries, and the decision has already been made that the eye, the nose, and the fish cannot be even partially duplicated economically. It is a grotesque but very real situation that economics dictate that millions can be spent to make better deodorants, but that very little can be spent to make sure the water people drink is not polluted.

There are many laboratory procedures which can be followed to determine if a sample of water is dangerously polluted, but these methods suffer the obvious disadvantages that they spot the pollution quite some time after the fact, and they are neither fast nor automatic.

At the present stage of our progress we are limited to monitoring differences from normal conditions and then determining in the laboratory what has caused these differences. Again, economics dictate that the monitoring we do be done with instruments already developed for other purposes, rather than ones developed specifically for our needs.

In discussing analyzers for measuring water quality, it is well to keep in mind that we are not always sure of exactly what it is we are looking for in the stream whereas in the process industries the analyzers are being used in places where the components in the process are known and we merely want to know how much of each component is present.

In measuring water quality, we must accept the fact that continuous analyzers will give us an incomplete answer. It is extremely important, however, that we recognize that these analyzers will pay for themselves over and over by narrowing the search for the cause of pollution - the second basic problem we have. By alerting us to the fact that a change in the water quality has taken place, and by giving us a clue as to what might be causing the pollution, these analyzers become valuable working tools.

In selecting analyzers for continuous monitoring, we are wise to aim at rugged, reliable instruments whose simplicity makes them relatively maintenance-free. It would be gilding the lily to use a $10,000 instrument requiring daily attention if it only pointed in a general direction to the cause of pollution. Certainly if a laboratory man is going to have to make the final determination anyway, he should be pointed in the right direction by the simplest, quickest and most economical way possible.

A brief review of available, rugged analytical equipment is worthwhile. In all cases discussed below, the instrument can be used continuously at an unattended station and the measurement can be transmitted to a remote location by any of the available transmitting methods.

The hardware available will be discussed first, and then the applicability of this hardware to pollution monitoring.

pH

The most reliable and sensitive method of measuring hydrogen ion concentration is by the use of two electrodes; one having a special glass tip sensitive to hydrogen ions, and the other a reference electrode whose voltage remains constant no matter what the solution composition. Until recently, maintenance of a pH measuring system was costly, because the high input resistance preamplifiers used drifted considerably and required frequent standardization. The electrode voltage was measured by these preamplifiers and retransmitted to a recording potentiometer. A year ago there came on the market a recording potentiometer of sufficiently high input resistance to obviate the need for an intermediate amplifier. In addition, this recorder is essentially drift free. Thus, pH has been elevated to the low maintenance stage and can be used successfully in an unattended station. The electrodes can be immersed directly in the water being measured and the recorder mounted on the shore nearby.

CONDUCTIVITY

The current-carrying ability of a solution depends upon the number of ions present, thus, a measurement of its conductivity tells the total number of ions in the solution.

The measurement is made by imposing an a-c voltage across a pair of carbon or platinum electrodes. This cell is in one arm of a Wheatstone bridge, and the instrument records the conductivity of the solution.

It is relatively well known that the activity of the ions in the solution varies with the temperature. Therefore, the conductivity of the solution will vary with the temperature of the water. There is difficulty in that the conductivity/temperature coefficient varies with the compound in solution. For example, the ratio of the temperature coefficient for hydrochloric and acetic acids is 16:1. Obviously there is no simple way to compensate for temperature change. It is best to determine what compounds would normally be present in the particular water being measured, and to use an average temperature coefficient. Temperature compensation is accomplished by using a thermistor bulb inserted into the water and tied into the measuring system so that, with the same solution, a change in temperature keeps the pen at the same reading.

TURBIDITY

In this type of instrument a light beam is either transmitted through or bounced off a sample stream of water. The measurement can be sent directly to a recording potentiometer. One of the difficulties encountered with this instrument is that the windows admitting the light become dirty and must be cleaned. Naturally, the amount of maintenance will vary with the dirtiness of the sample stream. A minor problem is that the element cannot be placed directly in the stream, but, rather, a sample must be pumped to the analyzer.

DISSOLVED OXYGEN

Much work has been done - and is being done toward finding a reliable means of continuously measuring dissolved oxygen. However, even the most promising of the methods to date is sensitive to variables other than oxygen content. The continuing development of these analyzers should make them more reliable and simple soon. Meanwhile, we recommend that they be installed in Class A stations. In most of the analyzers under development, the measuring circuit of a standard recorder will be used, permitting remote transmission of the data by any of the standard means.

OXIDATION-REDUCTION POTENTIAL

One of the simplest of the analytical measurements is that of oxidation-reduction potential. Two electrodes are used; a reference electrode such as that used in pH measurement, and a platinum electrode which detects the ORP. A recording potentiometer with an input resistance 5 megohms or higher is needed.

An ORP measurement gives the ratio of oxidants to reductants in a solution. It is used mostly to determine the extent to which a reaction has proceeded. There will be more discussion of its use later in this paper.

CHLORINE DEMAND

A measurement which has some possible application is that of continuous chlorine demand. While chlorine demand is non-specific, a measure of this factor provides us with an index of the presence of such strong pollutants as cyanide and chromate, as well as changes in the organic loading on a stream. For example, sudden increases might indicate the presence of cyanide and sudden decreases, the presence of chromate. This would have little or no value as an absolute measurement, but as a relative measurement could be used for the detection of many abnormal situations.

Figure 80 illustrates a practical method for measuring chlorine demand continuously. It consists of a residual chlorine controller which adds chlorine to a sample to maintain a constant residual at the end of a fixed time period. The signal operating the hypochlorinator to maintain the fixed residual is proportional to the quantity of chlorine required or the chlorine demand. Such a method is probably most easily implemented by pneumatic control and transmission although electronic is also practical.

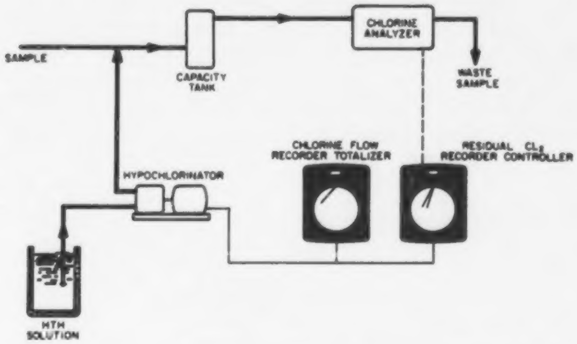

Figure 80. CONTINUOUS CHLORINE DEMAND MEASUREMENT

APPLICATION OF ANALYZERS TO POLLUTION MONITORING

As mentioned previously, these analyzers are most useful for indicating that a change has taken place in the condition of the stream. By observing what each of the analyzers has shown at the time of the change, and knowing something of the possible pollutants in the particular stream, the chemist can use these symptoms to diagnose the cause of pollution.

Some of the pollutants which will affect the indicated measurements are as follows:

pH:
- Amines
- Phenols
- Synthetic detergents
- Ammonia
- Cyanides
- Acids
- Bases

Conductivity:
- Amines
- Phenols
- Synthetic detergents
- Chlorides
- Sulphates
- Total dissolved solids
- Cyanides
- Cyanates
- Chromates
- Bicarbonates

Turbidity:
  Coliform
    Organisms
  Algae
  Silt

ORP:
  Oxidants
  Reductants

Chlorine demand:
  Coliform
    Organisms
  Algae
  Cyanides
  Chromates

Dissolved Oxygen:
  Organic Wastes

pH AND CONDUCTIVITY

There has been some discussion in the past as to whether both of these measurements are necessary. Actually there should be no question of this, because, for example, a salt need not affect the pH of a solution whereas an acid will. Similarly, above a certain concentration of acid, the pH will not change significantly whereas the conductivity will.

The interrelation of changes in these two measurements or the lack of interrelation provides significant clues as to the probable pollutant.

OXIDATION-REDUCTION POTENTIAL

Of all the measurements mentioned, ORP is of the most marginal value for diagnosing pollutants. Since it measures the ratio of oxidants to reductants, a change in the measurement does not tell whether the oxidants have increased or the reductants have decreased.

Where the chemistry of an oxidation-reduction potential measurement has been understood, the measurement has proven to be invaluable. For example, in the oxidation of cyanide wastes to cyanate and the subsequent oxidation to carbon dioxide and nitrogen, it has permitted continuous, automatic control of a process formerly extremely difficult to control. The same pattern has existed in the treatment of chromate wastes.

Unfortunately, ORP has been misused in some applications. For example, it has been used to measure residual chlorine content of treated water. This is impractical, because the potential of the solution is not affected exclusively by chlorine, but also by any other oxidants or reductants in the solution.

TEMPERATURE

While temperature measurement is certainly not an analytical measurement, it has been included because it can point to a source of "thermal pollution". Unfortunately it is very unspecific because a change in temperature of the stream may only mean that the sun was out or that it rained. However, when a change in temperature occurs and cannot be explained by climatic conditions, it points out that someone is dumping hot or cold wastes not normally put into the stream.

SUMMARY

The practice of using Class A and Class B stations, as adopted by the weather bureau, is logical for use in pollution monitoring. We have discussed the measurements which we consider practical for such stations. It is essential to note that these analytical measurements can narrow the search for the source of pollution, but not tell directly what the pollution is. It is uneconomical to develop continuous analyzers to identify the specific pollutant. It is best to use standard process instrumentation already developed for other process industries.

AUTOMATIC CONTINUOUS FLOW COLORIMETRIC AND TITRAMETRIC ANALYZERS AND TURBIDIMETERS*

CLIFFORD HACH, Hach Company, Ames, Iowa

In this paper I plan to cover only one mechanical type of automatic analyzer, because of the limited time and broad subject matter. Both colorimetric and titrametric analyzers will be covered.

In both automatic colorimetric and titrametric analyzers there are the mechanical processes of (1) measuring out the sample to be analyzed, (2) measuring out and adding the required chemical reagents for color development and/or for titration (3) measuring the color developed or the volume of titrant solution used.

This paper will concern only continuous flow colorimetric and titrametric analyzers, and for purposes of easy explanation, a description will be made about these analyzers as they are applied to water analysis.

Continuous flow analyzers are those in which the water sample flows in a continuous constant rate stream through the analyzer and the required reagents are added continuously to the water sample stream. In the case of a continuous colorimetric analyzer, the color that is developed in the analysis is measured continuously as the prepared sample flows through a photoelectric colorimeter. In this type of analyzer, most of the colorimetric analyses can be made on water such as chlorine, fluoride, pH, iron, silica, phosphate, etc.

In the continuous titrametric analyzer, the water sample flows at a constant rate, the indicator is added to the water sample stream also at a constant rate, but the titrating reagent solution is added to the water sample stream at a rate of flow that is proportional or equivalent to the concentration of the substance being analyzed for in the water sample stream. This type of analyzer is really a flow rate titration analyzer. Titration analyzers are applied to the analysis of water for total hardness, phenolphthalein and methyl orange alkalinity, etc.

Principally, a discussion will be made of the use of capillary flow tubes for metering the water sample and reagent solutions, at constant rates of flow in automatic analyzers.

Capillary tubes are tubes of very small inside diameter. Over a hundred years ago Poiseuille studied the flow of liquids through small diameter tubes and developed what is known as Poiseuille's Law. This is written mathematically:

$$\text{Rate of Flow} = \frac{KPD^4}{VL}$$

K = constant
P = pressure
D = diameter of the tube
V = Viscosity of the liquid
L = Length of the tube

It is seen that the rate of flow is directly proportional to the pressure. The diameter and length of the tube are constants, and at a given temperature the viscosity of the liquid is also a constant. Experimentally, it has been found that Poiseuille's equation is entirely rigorous, and therefore a high degree of accuracy can be obtained in metering liquid flows with the use of capillary flow tubes.

In most analyzers a water sample flow rate of 5 ml. per minute is a practical rate. A capillary tube two inches long, with an approximate 0.020" inside diameter and operating under a water head of 6" will give a flow rate of 5 ml. per minute.

A description will be made of the design of each part of automatic analyzer which use capillary metering flow tubes. To begin, all analyzers require a constant flow of water and usually this is at a rate of 5 ml. per minute.

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* Patent application has been made on the instruments described in this paper by the Hach Chemical Company.

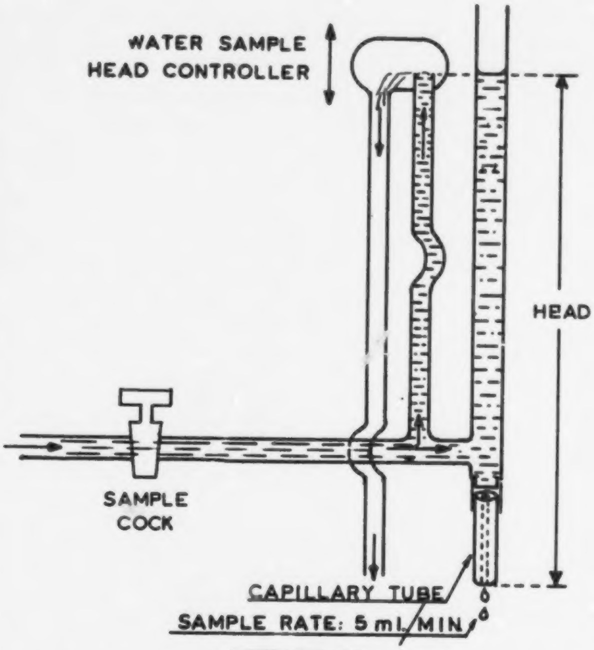

Figure 81. CONSTANT FLOW DEVICE FOR AUTOMATIC WATER ANALYZER

This can be accomplished with the device shown on Figure 81.

With the above device, the sample cock is opened so that a very small stream of water overflows the water sample head controller. The actual rate of flow is not too important -- the important requirement is that there is water overflowing the head controller and in this condition the head will remain constant. A sightglass or standpipe is connected to the water sample head controller, and this indicates the head of the water sample. A capillary flow tube is connected to the base of the standpipe, and this tube is, of course, under a constant head. Thus a constant rate of water sample will flow through the capillary. The capillary is in a vertical position with the water flow downward. It has been found that solid particles less than the diameter of the tube pass through the capillary tubes without collecting on the walls of the tube. The above water sample metering system will operate perfectly providing there is no chemical deposit or bacterial slime growth in the capillary tube. On most waters, such deposits usually develop in a short time, and their prevention will be discussed later.

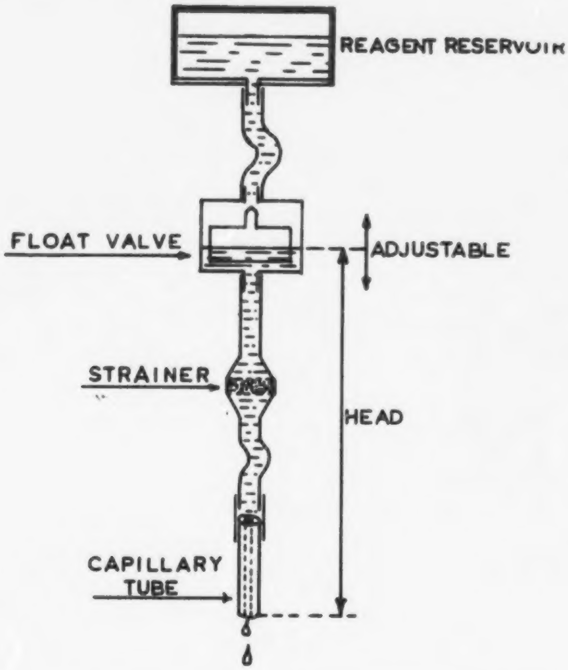

Figure 82. REAGENT METERING SYSTEM FOR AUTOMATIC ANALYZER.

Next a system for metering the reagents will be described. (See Figure 82).

Putting these two units together along with a photoelectric colorimeter gives the simplest continuous colorimetric analyzer, as shown in Figure 83.

This analyzer is applicable to analyses which require only one reagent solution, such as orthotolidine method for chlorine, colorimetric pH, colorimetric hardness, silica, phosphate, etc.

This colorimetric analyzer will operate satisfactorily on determinations in which no precipitate is formed in the reaction, and where the turbidity of the sample is rather constant or absent. A rapidly changing turbidity would render the analyzer unsatisfactory.

As mentioned earlier, chemical deposition or mold growth is not permissible in this type of analyzer. With properly formulated reagent solution the analyzer will operate indefinitely

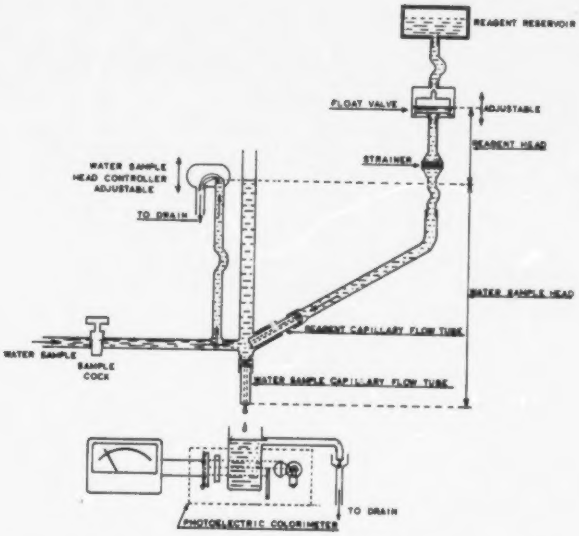
REAGENT RESERVOIR
FLOAT VALVE
ADJUSTABLE
REAGENT HEAD
STRAINER
WATER SAMPLE HEAD CONTROLLER ADJUSTABLE
TO DRAIN
WATER SAMPLE HEAD
REAGENT CAPILLARY FLOW TUBE
WATER SAMPLE
SAMPLE COCK
WATER SAMPLE CAPILLARY FLOW TUBE
TO DRAIN
PHOTOELECTRIC COLORIMETER

Figure 83. APPLICATION OF REAGENT METER AND CONSTANT FLOW DEVICES TO PHOTOELECTRIC COLORIMETER.

without needing cleaning, and the capillary flow system will give entirely constant rates of flow.

The analyzer shown in Figure 83 has a vertical adjustment on both the water sample head regulator and the reagent float valve. With these two adjustments, it is possible to adjust independently the rates of flow of both the water sample and the reagent solution.

The photoelectric colorimeter is a typical instrument that uses a selenium photocell coupled directly to a meter. The electric bulb operates at less than rated voltage and thus has a long life. The bulb voltage is supplied by a voltage regulating transformer such as a Sola or Raytheon transformer which maintains the voltage within ±1/2% accuracy. It has been found that if the colorimeter is contained in a tight case, the heat from the lamp keeps all parts of it warm, and this effectively prevents fogging of the optical surfaces with the familiar fog that accumulates on objects in a chemical laboratory atmosphere. This type of colorimeter is stable so that there is essentially no drift in a 30 day period.

Many colorimetric analyses require the addition of two or more reagents. Such is the case for the analysis for silica in demineralizer effluent. In this case phosphate is absent, so that two reagents are all that are required. An analyzer for silica is shown in Figure 84.

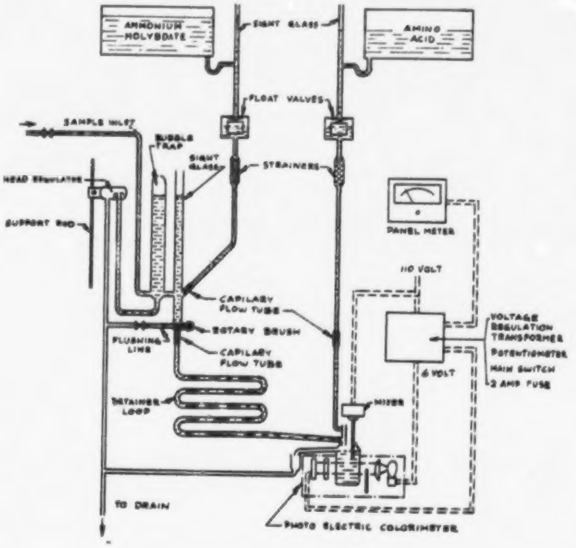
AMMONIUM MOLYBDATE
SIGHT GLASS
AMINO ACID
FLOAT VALVES
SAMPLE INLET
BUBBLE TRAP
SIGHT GLASS
STRAINERS
HEAD REGULATOR
SUPPORT ROD
PANEL METER
110 VOLT
CAPILARY FLOW TUBE
ROTARY BRUSH
FLUSHING LINE
CAPILARY FLOW TUBE
VOLTAGE REGULATION TRANSFORMER
POTENTIOMETER
MAIN SWITCH
2 AMP FUSE
6 VOLT
RETAINER LOOP
MIXER
TO DRAIN
PHOTO ELECTRIC COLORIMETER

Figure 84. SILICA ANALYZER WITH FEEDS FOR TWO REAGENTS.

In this analyzer a detention loop is used to hold the sample for five minutes after the addition of the ammonium molybdate reagent.

This allows time for the reaction between the ammonium molybdate and silica to take place. The water sample and molybdate stream then discharges into the colorimeter cell. The amino acid reagent stream is fed into this colorimeter cell also, and this produces the molybdenium blue color proportional to the amount of silica in the water stream. The color is measured by the photoelectric colorimeter.

The two reagent type analyzer can be used for such determinations as iron, phosphate and fluoride in water.

TITRAMETRIC ANALYZERS

The same system of metering the water sample and reagent solution can be used to build up a titrametric analyzer in which the titrating solution is made to flow at a rate proportional to the constituent being analyzed for in the water sample stream. Such an analyzer is shown in Figure 85. This type of analyzer can be called a "Flow Rate Titrator".

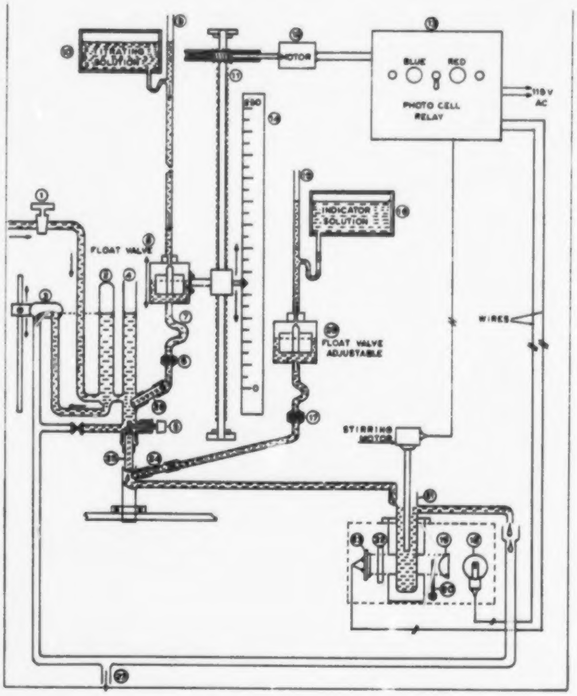

Figure 85. CONTINUOUS TITRAMETRIC ANALYZER.

This analyzer can be applied to most any titration analysis in which there is an indicator color change at the end point and in which there is no precipitate formed in the reaction. For purposes of explanation, a description will be given of the analyzer as it is applied to the titration of total hardness of water by means of the EDTA method using Erio Chrome Black T indicator. In this case, a water sample stream is made to flow at a constant rate of 5 ml. per minute through the water sample capillary metering tube and through the colorimeter sample cell.

A solution of buffer-indicator is contained in the upper reservoir (16), and feeds to the indicator float valve (28), and from there it flows at 0.1 ml. per minute through the indicator capillary (24) and joins the water sample stream just as the water enters the colorimeter sample cell (21).

A standard EDTA titrating solution is contained in a reservoir (10) at the top of the analyzer cabinet. It is connected by means of a flexible tube to a float valve (8) which is also connected with a flexible tube (7) through strainer (6) to a capillary metering tube (26) which empties into the water sample stream. The EDTA float valve (8) is attached to a nut on a long vertical screw (11) so that the float valve can be screwed upward and downward. Raising the EDTA float valve increases the EDTA head on the capillary (26) and thus increases the rate of EDTA flow through the capillary tube. Lowering the EDTA float valve decreases the rate of EDTA flow. The flow rate of EDTA solution is a linear function of elevation of the float valve, and its rate is adjustable from zero when the float valve is at its lowest position to a maximum rate when the float valve is in the highest position.

A red color filter (22) is used in the photoelectric colorimeter. Erio Chrome Black T indicator is red in color before the titration end point is reached, and changes sharply to blue when the end point is reached.

The water sample stream plus indicator gives a red colored solution in the colorimeter liquid cell (21), when there is a deficiency in the rate of flow of EDTA solution required to sequester the hardness in the water sample. Under these conditions a strong light reaches the photocell (23) in the colorimeter because the liquid is red and a red color filter is used. This causes the thyratron relay (13) to close, which in turn causes the screw driving motor to turn in the direction of increasing the elevation of the EDTA float valve. The process continues until a float valve elevation is reached which causes an EDTA flow rate to be reached which is large enough to be equivalent to the hardness content of the water sample stream. At this time the Erio Chrome Black T indicator changes sharply to blue. This causes a light interference to take place in the photoelectric colorimeter such that a very dim light reaches the photocell. The thyratron relay then opens which in turn reverses the direction of rotation of the screw driving motor. The

EDTA float valve now is screwed to a lower elevation, and in a short time the EDTA flow rate decreases enough to cause the indicator to change back to red again, and the whole process repeats.

Thus the titrametric analyzer is a continuous end-point seeking instrument. It continually hunts. A pointer attached to the EDTA float valve indicates the p.p.m. hardness in the water sample, on a scale (14) which is sixteen inches long. The hunting cycles amount to approximately 1/4 inch on a typical hardness analyzer. In order to permit the indicating pointer to remain stationary during the normal up and down hunting movement of the EDTA float valve, adjustable gap is built into the system. A cable driven slide wire potentiometer is coupled to the indicator pointer which can be coupled to a millivolt recorder to record the analysis.

This type of titrametric analyzer is applicable to color change titration in which no precipitate is formed in the reaction.

TURBIDIMETERS

There are two basic systems for the measurement of turbidity in water:

1. Light Absorption
2. Light Scattering (Nephelometry)

Light absorption system is best adapted to the measurement of high ranges of turbidity, such as above 100 parts per million. It is not satisfactory at all for use on very small amounts of turbidity such as in filter water where the turbidity is less than 5 p.p.m. because the absorption of light by the turbidity in the water is so small. The measurement of turbidity by light absorption is carried out the same as colorimetric analyses are made. A photoelectric colorimeter type of instrument is used. Such an instrument is shown in Figure 86.

A much more sensitive and satisfactory way to measure turbidities in the range of 1000 parts per million and below is the light scattering or Nephelometric method. One type of instrument used is as shown schematically in Figure 87.

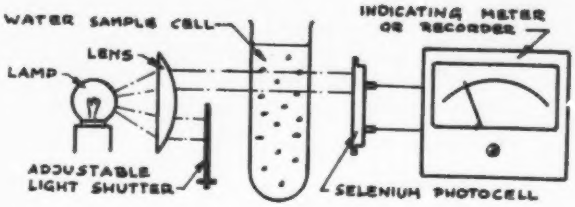

Figure 86. PHOTOELECTRIC COLORIMETER.

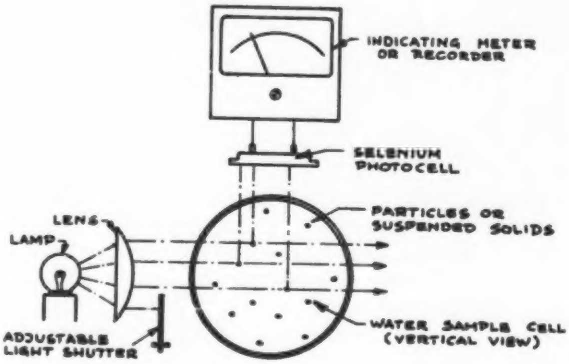
INDICATING METER OR RECORDER
SELENIUM PHOTOCELL
PARTICLES OR SUSPENDED SOLIDS
LENS
LAMP
ADJUSTABLE LIGHT SHUTTER
WATER SAMPLE CELL (VERTICAL VIEW)

Figure 87. THE NEPHELOMETER.

It is seen that the particles of suspended solids which are present in the water sample reflect or scatter light in all directions. Some of the scattered light emerges from the sample cell at right angles to the original light beam, and falls upon the photocell. The output of the photocell is registered by the meter or recorder.

The amount of light reaching the photocell is directly proportional to the amount of suspended particles in the water sample. If there are no suspended particles, there is no light scattering and then no light reaches the photocell. Thus the meter reads zero on perfectly clear water.

An advantage of this type of instrument is that the meter reads up scale in proportion to the amount of turbidity. A very important feature of Nephelometry is that a very intense light can be used which results in a high degree of sensitivity of turbidity measurements. Thus it is possible to design instruments which will give a full scale meter reading on as little as one part per million turbidity. It is possible to measure turbidities as low as 0.01 p.p.m.

Figure 87 illustrates the conventionally designed Nephelometer. It has one serious operating difficulty which results in the need for very careful operator technique. The glass water sample cell must be perfectly clean in order to avoid light scattering from films on the walls of the glass tube itself. Figure 88 illustrates light scattering by deposits on the glass tubes.

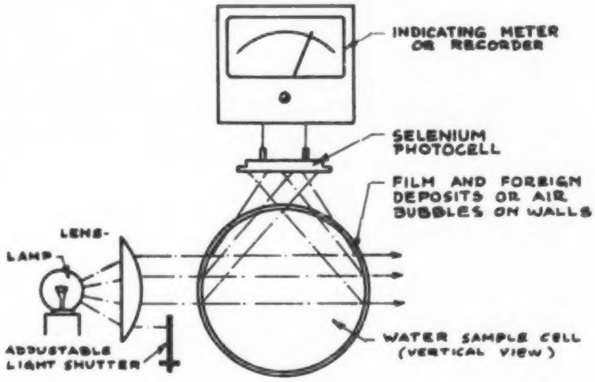
INDICATING METER OR RECORDER
SELENIUM PHOTOCELL
FILM AND FOREIGN DEPOSITS OR AIR BUBBLES ON WALLS
LENS
LAMP
ADJUSTABLE LIGHT SHUTTER
WATER SAMPLE CELL (VERTICAL VIEW)

Figure 88. LIGHT SCATTERING IN NEPHELOMETER BY DEPOSITS ON THE GLASS TUBES.

The light that is scattered by the fouled glass surfaces results in abnormally high turbidity readings. The magnitude of this source of error can be very, very large. This matter cannot be over emphasized. In fact, there is usually some haziness in the glass of the glass tube itself which results in some light scattering. Any scratches or draw marks in the glass tube also scatter light.

If the type of instrument shown in Figure 87 is to be adapted as a flow through continuous Nephelometer, air bubbles will almost certainly collect on the walls of the glass tube; likewise, a natural fouling will take place. The result is that a Nephelometer of the conventional design, as shown in Figure 87, is unsatisfactory as a continuous flow type instrument.

To avoid these problems a new design of Nephelometer has been developed for continuous flow use in which the light beam enters the water sample from above the surface of the water. This instrument is shown in Figure 89.

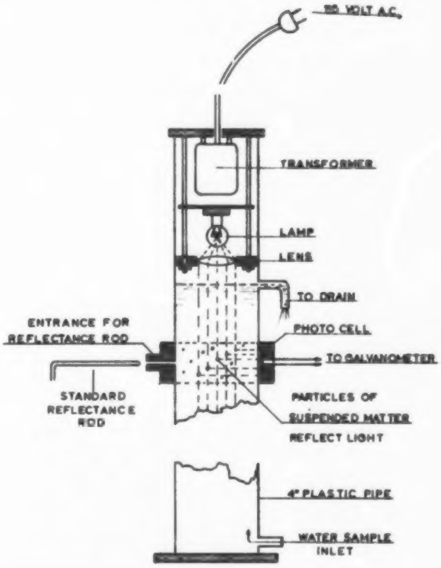
110 VOLT A.C.
TRANSFORMER
LAMP
LENS
TO DRAIN
ENTRANCE FOR REFLECTANCE ROD
PHOTO CELL
TO GALVANOMETER
STANDARD REFLECTANCE ROD
PARTICLES OF SUSPENDED MATTER REFLECT LIGHT
4" PLASTIC PIPE
WATER SAMPLE INLET

Figure 89. LOW-RANGE TURBIDIMETER (HACH).

Water enters the bottom of the turbidimeter body and overflows an outlet. This results in a continuous flowing water surface which floats away foam and scum. The surface of the water is mirror smooth and clean.

The instrument in Figure 89 is an excellent instrument for very low range measurements. It does have optical windows in front of the photocells which are in contact with the water. Fouling of these surfaces results only in a partial absorption of the scattered light which is headed toward the photocells. It does not result in the extremely serious errors that result when the glass tubes become fouled in the conventional Nephelometer as shown in Figures 87 and 88.

It has been found in actual long term operation that the windows in the instrument shown in Figure 89 need cleaning approximately every six months when the instrument is used to monitor filter effluent, which is usually very clear water.

In all types of turbidimeter, it is necessary to standardize the response of the instrument so that the meter reading can be made to indicate the amount of turbidity present in the water. This standardization adjustment must be checked periodically and any readjustment that is necessary be made.

The most direct way to standardize a turbidimeter is to fill it with water of a known turbidity, and then adjust the light shutter, or meter shunt so that the correct meter reading is obtained. In standardizing instruments which are used to measure very low turbidities, it is very difficult, if not nearly impossible to prepare known standard turbid waters, such as exactly 1.00 p.p.m. turbidity. Also, the mechanics of washing out and filling a turbidimeter is time consuming and troublesome. For this reason mechanical reflectance standards have been developed to make standardization checks easy. These consist of reflectance rods which may be inserted into the turbidimeter body, in the light beam in front of the photocell windows. A 1/8 inch diameter polished stainless steel reflectance rod was found to give the same reflectance as five parts per million turbidity. A glass rod 1/8 inch diameter reflects as much as 0.5 parts per million turbidity.

Standardization is accomplished by inserting one of the rods into the turbidimeter, as shown in Figure 90, and noting the meter response. The meter shunt is adjusted so that the desired response is obtained. This provides a convenient method of standardizing the low range turbidimeter.

For the measurement of turbidities in the range of 5 to 1000 parts per million, a somewhat differently designed Nephelometer has been developed. This is shown in Figure 89.

Here six photocells are arranged in a ring surrounding the lens, and are located above the water surface. These photocells pick up light that is reflected backwards, rather than at right angles to the light beam as in the usual Nephelometer. The amount of light reflected backwards is much less than at a right angle, and thus the instrument is not suitable for measuring small amounts of turbidity.

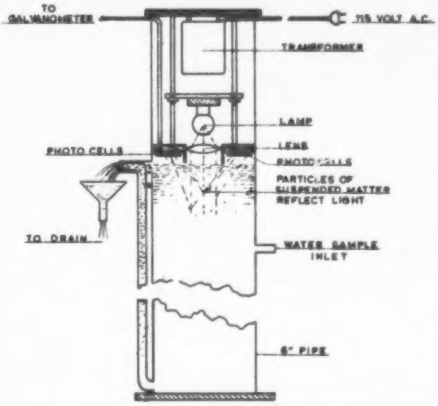

Figure 90. HIGH-RANGE TURBIDIMETER (HACH).

The entire optical system in this instrument is above the water surface and therefore is not fouled by deposits or air bubbles from the water. No routine cleaning is necessary because the unit is closed and the lens and photocell assembly remain warm from the lamp, and this prevents any condensation on the unit.

In both the high and low range turbidimeters shown in Figures 89 and 90, the measurements are made from within the body of the water sample itself, well removed from the wall surfaces of the turbidimeter body. The light beam does not fall upon the wall surfaces near the photocells, so any fouling or air bubbles on these surfaces do not cause light reflections that reach the photocells.

In both instruments, the approximate 24 inches of turbidimeter body that extends below the photocells serves as a light trap. The light beam strikes the bottom of the turbidimeter body and is reflected in all directions. This reflected light is effectively dissipated so that essentially none reaches the photocells.

The high range turbidimeter shown in Figure 90 is arranged so that there is a continuous discharge of water sample from the bottom as well as from the upper water surface. This discharges settleable solids so that there is little solids accumulated in the bottom of the turbidimeter.

INSTRUMENTATION (PART II)

DISCUSSION

MR. GILBERT V. LEVIN (Resources Research, Inc., Washington, D.C.): Mr. Dixon, is there a gas water interface while the water is going through the hydraulic cyclone and an inlet pressure of 50 psi? I wonder if you might not get an increase in the apparent partial pressure because of the effect of the centrifugal field on the water.

MR. WILLIAM S. DIXON (Chief Engineer, Analytical Instrumentation, Hays Corp., Michigan City, Indiana): Let's go back to slide number 9. (Figure 62) The 50 pounds is on the inlet to the aspirator. When we drop across the aspirator we have a recovery on the system and the unit functions at about 3 to 5 pounds. It is independent of the operating pressure. We always come to equilibrium at some pressure. (Slide is shown). The 50 pounds that I spoke of is here, (inlet to aspirator) and we drop it through a rather small orifice in this aspirator. If we opened this up completely (points to water outlet valve) it would drop to atmospheric pressure. But we have a back pressure fixed by an orifice. Depending upon the air rate, we are going to have a fixed point here (at the cyclone separator). You have to get into this further to understand it completely, but all we are interested in here (pointing to cyclone gas exit) is a constant pressure. That is, we don't care what the pressure is as long as it is constant. We have a constant pressure on the water, it is a totally enclosed system and we are dropping through a fixed orifice here. Thus there is a pressure here at a fixed point (points to pressure gage) flowing through the system. There are regulators here (at the pump) so we hold a constant flow of water. This pressure is normally run between 3 and 5 pounds, because when it is running between 3 and 5 pounds we know that we are delivering about a gallon a minute which gives us a time constant of about two minutes. If you drop the pressure at this point to 25 pounds you still have water going through and you will have half a pound recovery pressure here, but since you have a small quantity of water, you won't have the circulation gas we want; it still reads correctly but takes it longer to reach its new equilibrium to change.

"Why" this partial pressure, is quite an involved thing. It is just at new equilibrium level. I referred to equilibrium at 760 millimeters. Since we are measuring partial pressures we don't care where it is as long as it is at equilibrium.

MR. KOCH (Johns Hopkins University): Can you measure super saturation in water?

MR. DIXON: The range on this unit is from zero to 500 per cent saturation or its' equivalent parts per million. This would be 50 parts per million at 20 degrees centigrade.

MR. ALVIN MORRIS (Research Assistant, Biology Department, Lehigh University, Bethlehem, Pennsylvania): You have had trouble with detergent foaming. Have you got that licked?

MR. DIXON: Yes, when we encounter heavy detergent foaming we inject an anti-foam agent into the inlet of the pump. The heaviest foaming condition we have ever run into was in a pulp mill, and something like a pint of anti-foaming agent every 48 hours had far beyond the required ability to squelch this foaming.

MR. WILLIAM H. DAVIS, SR. (Water Resources Section, PHS, Dallas, Texas): How do you separate grease and other heterogeneous solids in that machine?

MR. DIXON: In this unit the smallest hole that it has to go through is in the aspirator, and that is approximately eighty-one-thousandths. So we screen this through a 25 mesh screen with a number 16 wire. (Something that just has a smaller hole diameter than the orifice in our aspirator.) We have run this in practically every condition of high solids content that we have encountered. We haven't had any trouble except when the grease blinds the screen. Now we have had a case where there has been trouble with blinding of a filter screen. But this doesn't cause the instrument to fail, other than it just doesn't receive its water sample. Anything that will go through a 25 mesh screen will go through this entry.

MR. RICHARD L. WOODWARD (Robert A. Taft Sanitary Engineering Center): Mr. Deutsch, you mentioned something of COD analysis. I wonder if you know of any one who is doing any work on the development of a COD analyzer?

MR. A. DEUTSCH (Principal Research Engineer, Research Dept., Brown Instrument Division, Minneapolis-Honeywell Regulator Co., Philadelphia 44, Pennsylvania): No, I don't. I have talked with some people who have ideas, but nobody has gone into it yet. I can't say we will, but I am sure we are looking at it quite seriously. We all know that COD is probably easier to get than BOD. It might have a little more practicality of continuous measurement. However, I think we are about two years at least from a practical determination of this type.

MR. ERWIN COHEN (Research Chemist, American Machine and Foundry): I am a little lost as to the exact purpose of all these analysis methods which have been mentioned. Let's say you had a magical instrument that could tell you exactly what the gamut of contaminant was, such as analine or some other contaminant in the stream. What would you then propose to do with this information? Go back to the fellow who dumped it in and tell them you can't do it? You could do this before you even analyzed for analine. Or would you treat the water to remove the analine?

CHAIRMAN GREEN: This is a very pertinent question. There are those in the various agencies in this country who have the responsibility for controlling water pollution who think that perhaps in addition to all this back up that we are trying to generate, continuation of actual monitoring of streams for long term purposes and immediate controls, we also should have better information from those who put the stuff in. What and when and how much and why they are putting it in. Now if we don't have that, if regulations or laws do not exist universally to provide us with that information, obviously we have to go out and try to find out what the character of the waters are through detective work, some of it extremely costly. If we find out that something is in the water that shouldn't be there, then obviously the water pollution control agency has some responsibility, and the degree of responsibility will differ depending upon the local situation.

MR. F. E. MOORE (Manager, Analyzer Group, The Foxboro Co., Foxboro, Massachusetts): I had a recent inquiry from a chemical company asking for an instrument to tell them how much salt they were adding to a stream. Their purpose was to convince the pollution authorities that they were not polluting the stream. My only comment is that if there were more companies who were doing this, the monitoring would be of much less importance.

MR. THEODORE OLSON (University of Minnesota): Dr. Parker, I would like to know exactly what device you used for the measurement of turbidity. You said you constructed the equipment yourself.

DR. PARKER: No, we made our own oxygen electrodes. We used a turbidimeter which is based on reflectance rather than transmission.

PROFESSOR OLSON: Which one?

DR. PARKER: This one is made by the Hach Chemical Company, and it amounts to a constant voltage light source, like an old-fashioned headlight, well aimed, and it has 6 selenium cells in series. This is mounted inside of a brass tube, four feet in length, painted flat black. In the presence of turbidity free water there is total absorption and no light reflected back to the photo cells. Up to at least 100 turbidity units in terms of Jackson Candle Standard, the output in millivolts is nearly a linear function of the turbidity. Actually we have gone up to several hundred, possibly 500 turbidity units in our calibrations. We know it is not linear in this range, but we know from the calibration curve we know what the turbidity is in terms of Jackson units.

PROFESSOR OLSON: The cost of this?

DR. PARKER: $325.00. - That is the instrument itself. It is very good and very stable. The only criticism I have with it, is that every once in a while we get a slight surge and get the photo cells dirty. But the standard once a week maintenance, which we have anyway, is adequate.

MR. ELWOOD BEAN (Water Department, Philadelphia): Is that a standard instrument or special?

DR. PARKER: No, Mr. Bean, it is just recently developed. Bill Klein was the first one to call my attention to it. We have three of them now, we have one running at our first station, we are putting one each in our two new stations.

MR. SAMUEL S. BAXTER (Water Commissioner, Philadelphia Water Department): This is more a comment than a question, but someone on the panel might want to pick it up. This again relates to the economics of the situation. We note that many people here are either concerned with regulatory bodies or with manufacturers of instruments, or with universities that are developing them. But if we are to justify economically the use of instruments, we are going to have to get back to the people who manage and operate the water industry, and we are going to have to convince them that there are savings involved that will pay for these instruments. I certainly recognize Mr. Babcock's point, although I think Mr. Deutsch had a slightly different viewpoint, i.e. we have had to get other industries involved. This water industry is big enough to pay for these if we only understand it. A city like mine spends a million three hundred thousand dollars for chemicals each year and if an instrument only saved 1 per cent, that capitalized would pay for an awful lot of instrumentation. Not many of us here are operators or management people. We've got to get this story back to operators and management in order that they will put the money up for instruments.

One other point? The regulatory agencies are non-productive. They don't do anything as far as raising money is concerned. It is where the revenue is that we've got to get the money for these instruments.

MR. BABCOCK: I would like to comment on Commissioner Baxter's statements. I agree with him wholeheartedly, but he is a pioneer in this field. No question about that. You know, after you get through knocking your head against the wall for a while and it gets bloody, you get tired of it. You get out and deal with the average water utility man who is a graduate of the Public Works Department, and who on the side is also the Dog Catcher and the Constable, and you have a great difficulty getting this message across. The people who agree with Mr. Baxter, and I am one of them -- are in the minority, because the water supply field, and it is also true of the sewage works field, is in the state of being translated from an art to a science. And we have a problem of properly trained personnel. This reminds me of an occasion I ran into several years ago in the little town of Provincetown, out on the end of Cape Cod. They had a flow controller whose sole mission in life was to limit the rate of flow from the wells so as to avoid salt water intrusion, and this was the traditional black box that hung on the wall. It was placed in service and within 24 hours it was inoperative. Servicemen looked it over and found some things that looked like somebody had been tampering. He put it back in service and it worked all right and within a matter of a few hours it was inoperative. This time the Superintendent took a little different tack, he had the instrument repaired then placed a notice on the board that regardless of the presence of this instrument it was not planned to retire or transfer any personnel. It was 9-1/2 years ago and there hasn't been a service man near it.

This is a true case, it is not out of my imagination.

So that this indicates the problem you are up against, and it is going to be one that is going to be corrected by evolution and not by revolution.

CHAIRMAN GREEN: There is one other possible source of cash for some of this developmental work. Mr. Cleary mentioned one such source this morning when he said that part of the money for the developmental work on the very fine instrumentation that you saw came from the funds granted to ORSANCO by the Public Health Service under Public Law 660. Now there are other mechanisms than that of the program grants to state and interstate agencies which can be used, and it is likely that certain monies can be made available on a research grant basis, if we can be convinced that we have, or that the states and the interstate agencies have real need for specialized equipment which is not now available.

Those of you in the hardware business might bear that in mind. I am making no promises, but I certainly know that we in the Public Health Service are going to have some need for equipment which is still not available, even though a great deal of progress has been made.

DATA HANDLING

Chairman: MILO A. CHURCHILL,
Chief, Stream Pollution Control Section,
Tennessee Valley Authority, Chattanooga, Tennessee

INTRODUCTION TO THE SYSTEMS CONCEPT OF AN AUTOMATED DATA ACQUISITION, TRANSMISSION AND PROCESSING SYSTEM

SAUL STIMLER, Development Engineer,
Laboratories Div., International Telephone & Telegraph Corp., Nutley, N. J.

ABSTRACT

This paper will introduce the systems concept for an automated water quality measuring system. The general technical considerations will be developed for a nationwide system which would be capable of serving the combined needs of the Department of Health, Education and Welfare, and those of the State and the Municipal governments. The paper will be directed primarily to the potential system users who may not be versed in the electronic considerations. To assist in presenting the material, the system will be divided into three major subsystems. There are:

1. Data Acquisition
2. Data Transmission
3. Data Processing Subsystems

For each of the subsystems, important operational characteristics of the major components will be considered.

A typical operation of a nationwide water quality measuring system servicing 300 U.S. Government and 4800 State water quality measuring stations will be considered to point out both the advantages and disadvantages of such a large-scale automated system.

In conclusion, some of the system planning considerations which may prove important to the ultimate success of the long range automatic system will be discussed.

To introduce the systems concept for an automated water quality measuring system, let us consider a system to fulfill the following operational requirements:

1. The system should be capable of servicing 300 unattended Department of Health, Education, and Welfare stations located throughout the United States.

2. Each station should be capable of monitoring up to 10 variables which typically might be dissolved oxygen, temperature, radiation, pH, chloride, alkalinity, hardness, color, turbidity, and specific conductance.

3. The system accuracy should be ±1% exclusive of the Sensing Elements.

4. Each variable should be sampled once every five minutes.

5. Dangerous levels of such critical variables as dissolved oxygen or radiation should be capable of being detected at the instant they exceed a preset level.

6. Under normal conditions, twenty-four hours of data should be transmitted from each station to the processing center once each day.

7. The necessary planning should be incorporated in the initial system design to permit future expansion to service State and Municipal water quality measuring stations. For the preliminary survey it will be assumed that 100 stations, each measuring 10 variables, will be located in each of the 48 states.

The above specifications are based on a brief examination of the system requirements and are used only to assist in introducing the systems concept. For an actual system design, a careful study of the systems requirements would be necessary.

Figure 91 illustrates the contemplated system. The circles are U.S. stations being serviced by the HEW data center shown as a square. The triangles are State and Municipal stations. These are shown tied to a diamond shaped State center and from there to the HEW center.

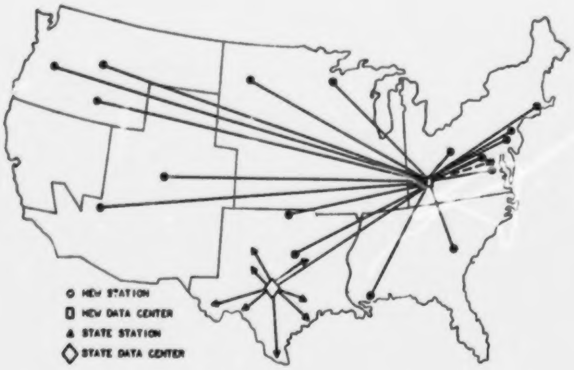

Figure 91. AUTOMATIC WATER QUALITY MEASURING SYSTEM.

Cincinnati will be considered as the HEW Data Center to permit discussion of a specific geographic system. Key centers such as Washington, D.C., may have inquiry lines (shown dashed) to the Data Center.

In operation each of the variables will be measured and the measured values stored for a 24-hour period at each of the unattended stations. At the end of a 24-hour period, the data will automatically be transmitted to the data center where it will be processed and the required water quality analysis reports will be automatically prepared. Alarm signals will be sent to the center as soon as they occur. A random access file will be assumed to be maintained at the Data Center so that various agencies may have access to this data by telephone line inquiry.

To examine the hardware and operational aspects of the system let us consider the system to be composed of three major subsystems:

The Data Acquisition Subsystem

The Data Transmission Subsystem

The Data Processing Subsystem

THE DATA ACQUISITION SUBSYSTEM

One Data Acquisition subsystem would be located at each remote unattended station. The functions of the subsystem would be to measure each variable, convert the analog signals to digital form and store the digital values for a 24-hour period at the end of which time transmission would be initiated to the Data Center. Alarm signals would be transmitted immediately. Figure 92 is a block diagram of the major components of the data acquisition subsystem.

In operation, the Scanner would connect each Sensing Element in turn to the amplifier. The output of the amplifier would be converted to digital form by the Analog-to-Digital Converter and the digitized signal would be stored in the storage unit, which typically might be magnetic tape, punched paper tape or punched cards. To help visualize the operation of the subsystem the voltages at the significant points are shown in the figure. At point (1) the output of the sensing element is an analog signal usually in range of 0 to 100 millivolts (mv). In the figure 0 to 10 mv was assumed. Hypothetical curves for oxygen and temperature, the first two variables to be sampled, are shown. At point (2) the output of each sensing element is connected for the required sampling period to the Amplifier once every five minutes.

During the sampling period the instantaneous voltage at points (1) and (2) are the same. At point (3) the amplified voltage of point (2) appears. At point (4) the digital equivalent of the voltage at point (3) appears. At any given instant, seven lines must be sensed to determine the voltage. Thus, during sampling time 1 the amplified oxygen signal is assumed to be 11 volts. This is represented by a simultaneous high on the first line representing the value 1, the second line representing the value 2 and on the fourth line representing the value 8. Thus the total value is 8 + 2 + 1, or 11. The odd parity bit on line 8 appears high when the digital number causes an even number of the lines 1 through 7 to be high simultaneously. The parity bit is used to permit checking the accuracy of the data as it is manipulated and transferred to other parts of the system.

The illustrated digital representation is but one of many which may be used.

The Control Unit performs all the timing and control functions. These include starting each set of measurements at the correct

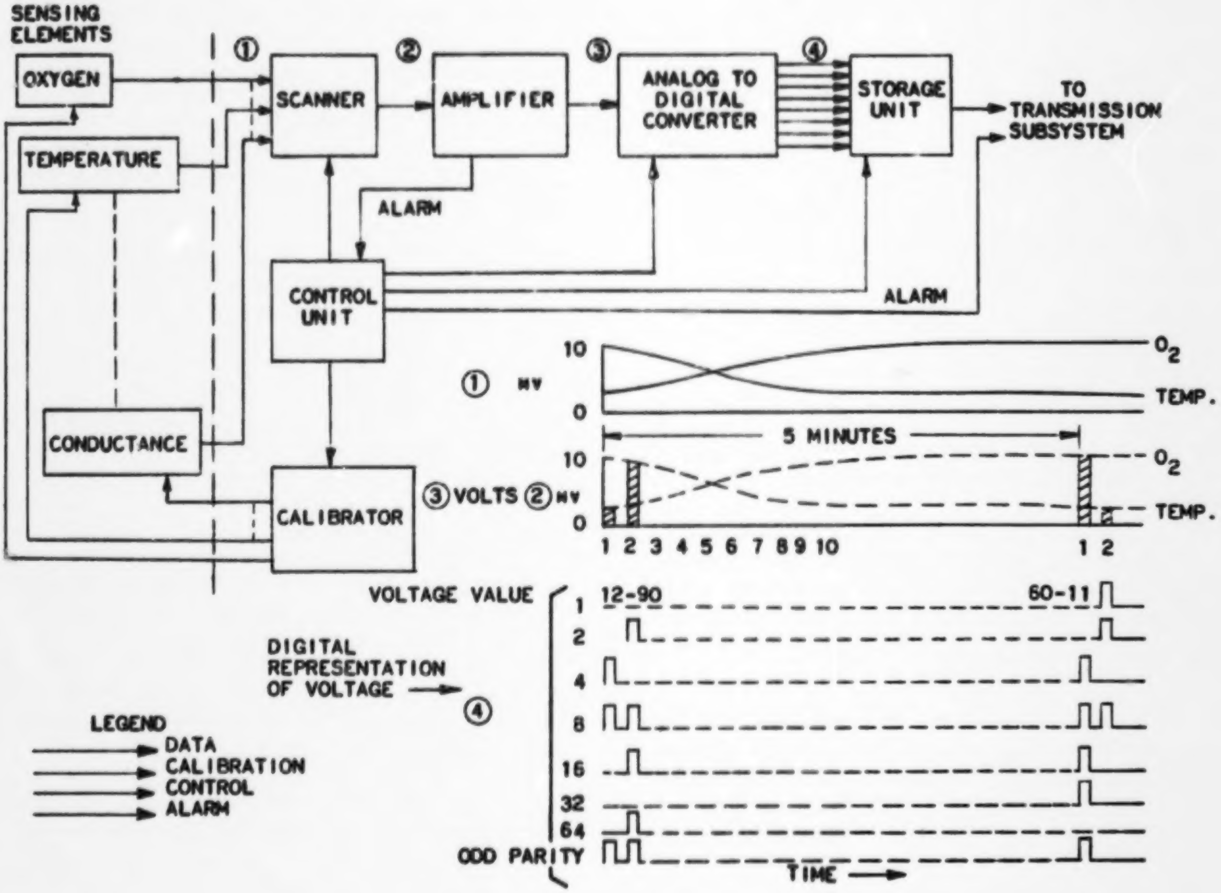
SENSING ELEMENTS
OXYGEN
TEMPERATURE
CONDUCTANCE
①
②
③
④
SCANNER
AMPLIFIER
ANALOG TO DIGITAL CONVERTER
STORAGE UNIT
TO TRANSMISSION SUBSYSTEM
ALARM
CONTROL UNIT
ALARM
CALIBRATOR
10
① MV
0
O2
TEMP.
5 MINUTES
10
③ VOLTS ② MV
0
O2
TEMP.
1 2 3 4 5 6 7 8 9 10
1 2
VOLTAGE VALUE
12-90
60-11
1
2
4
8
16
32
64
ODD PARITY
DIGITAL REPRESENTATION OF VOLTAGE ④
TIME
LEGEND
DATA
CALIBRATION
CONTROL
ALARM

Figure 92. BLOCK DIAGRAM OF DATA ACQUISTION SYSTEM

time, initiating transmission of the data once each day, sending the alarm signals when necessary and placing the proper identification on the stored data.

The Calibrator inserts a standard calibration voltage in each of the circuits when actuated by the Control Unit. This permits compensation for variations in the characteristics of the elements between the point where the calibration signal is inserted and the storage unit.

For ease and flexibility in processing of the data at the data center special information is inserted prior to each group of 10 measurements. These include a Start Measurement, Station Identification, and Time of Measurement, and at the conclusion of the 10 measurements an End of Measurement signal. We are now in a position to estimate the amount of data which must be stored, transmitted and processed per day.

To attain the required accuracy of ±1% using binary numbers as illustrated in Figure 92, a seven bit number would have to be used. This would permit expressing voltage values to 1 part in 128 or ±0.77%. Therefore, a seven bit binary number plus one parity check bit will be assumed per data point and identification character. Thus to store each set of 10 measured points per five minutes would require one eight bit character for each of the data measurements, and one eight bit character each for Start Measurement, Minute and Hour of the day and two characters for the Station Identification. The result would be 16 characters per set of 10 measured points. The total data accumulated per day would be *4600 characters per station per day. Assuming a punched paper tape storage unit at each station, a 1000 foot reel of tape would store approximately 30 days of data.

THE DATA TRANSMISSION SUBSYSTEM

The Data Transmission subsystem must provide the transmission link for digital information between the remote stations and the data center as well as between all other remote locations. For a system having a geographic distribution of the one discussed here, use of the existing telephone plant for the transmission medium is the only practical answer. The digital information as read from digital storage units is not suitable for direct transmission over such lines. Therefore at each remote station the line must be terminated in an equipment suitable for converting the data read from a storage unit into a form suitable for transmission. At the data center the transmitted data must be reconverted into the "one" and "zero" form shown in Figure 92 to be useful for the computer. For this reason another terminal equipment unit must terminate the transmission lines entering the data center to convert the transmitted information into the "one" and "zero" form suitable for the computer. In addition, speed buffering is necessary at the data center terminal. At present digital data is transmitted over available telephone lines at speeds between 750 and **1200 bits per second. Computers for economical operation should receive as input and transmit as output, data at rates in the region of 50,000 and 1,000,000 bits per second depending upon the speed of the particular computer. The terminal equipment at the data center must permit receiving data from the transmission subsystem at the relatively low transmission speed and supply this data to the computer at the relatively high computer speed.

Correction of transmission system introduced errors is another important factor which must be considered in the terminal equipment. Switching and other transient generating sources introduce errors into the transmitted data. Depending upon the reliability required, special check bits may be used by the terminal equipment to detect, automatically correct or detect and correct the data. The technical problems of transmission, of the medium, and of the terminal equipments will be considered in subsequent papers. As a general summary, the functions of the terminal equipments in the Data Transmission subsystem may be considered as follows:

1. The digital data at the transmitter must be converted to a form suitable for transmission over the medium; the data from the transmission lines must be converted into a form suitable for the computer.

2. Speed buffering must be provided at the Data Center.

3. The reliability requirement will determine whether automatic error detection together with error correction for the received data will be necessary. Reliability being the maximum acceptable percentage of erroneous characters in the data to be used for processing.

A brief look at some of the economic considerations may be useful before leaving the Data Transmission subsystem. Using the requirements assumed in this paper it would be necessary to transmit 37,000 bits per day per remote station. This could easily be accomplished in less than three minutes of transmission. Assuming for a moment that the terminal equipment was arranged to permit automatic connection and transmission of the day's data from each station at voice line long distance rates, the annual charges, neglecting alarm transmission, for line use

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* (16 characters per record (288 records per day) 4608 characters per day.

** ITT and other companies are transmitting data at higher speeds but for the purpose of this discussion factors of 2, 3 or 4 will not affect the point being made.

would be in the order of *$150,000 per year for the 300 HEW stations. One alarm transmission per station per day would double the cost. Considering the other extreme, namely, that the receipt of alarms was so important that 24 hour private line connections were necessary the cost without switching centers could be in the $4,000,000 region. These would be recurring costs, therefore, the line requirements must be carefully established.

THE DATA CENTER SUBSYSTEM

At the Data Center, the data from the remote stations must be received, processed, stored and various outputs generated. Figure 93 is a block diagram of such a center. The Transmission Terminal Equipment, though part of the Transmission Subsystem in this paper, may be largely incorporated in the computer when a modern multisequence computer such as the ITT SPE is used.

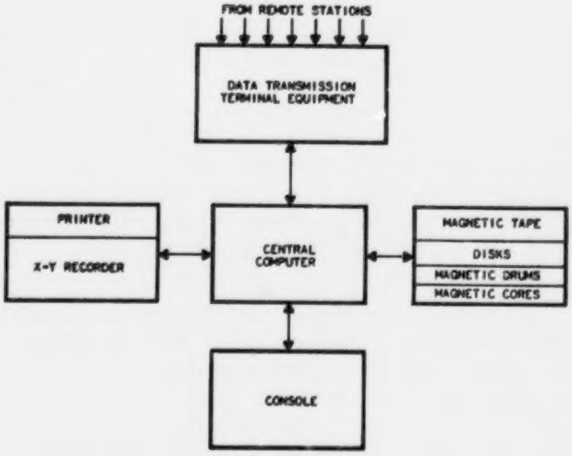

Figure 93. BLOCK DIAGRAM OF DATA CENTER SUBSYSTEM.

The stored program digital computer, which is the type most apt to be used in this application, consists of a Central Computer, Storage Unit, Input Unit, Output Unit and a Console for supervision and control of the computer operation. The ability 1) to perform a very large number of simple operations such as addition and subtraction per second and 2) to make simple logical decisions such as: "Is one quantity larger, smaller or equal to another?" - permits the stored program machine to perform its many complex tasks efficiently.

In operation a set of instructions, together with needed constants, called a sequence or program must be first prepared. Generally many such programs are stored on magnetic tape or drums. The data to be operated upon is also stored on tapes or drums. When a particular program is to be executed, it and the associated data, are transferred to a working storage which in high speed machines, is a core storage. The Central Computer contains the hardware to interpret the instructions, perform the arithmetic operations and store the results in appropriate storage. The output is frequently hard copy prepared by high-speed printers. When necessary, it could be on special formats for example, graphs prepared by X-Y recorders. A more detailed explanation of the computer operation will be given in the computer paper to follow. From the system's viewpoint the operational characteristics are of particular interest.

Operationally the data received from the remote stations must be:

1. Multiplied by the proper calibration constants to obtain engineering values - i.e., Temperature, pH, etc.

2. Stored in files which typically might be magnetic drums or magnetic tapes, depending upon whether immediate or future access is necessary.

3. Used to automatically generate printed hard copy reports which could include automatically generated graphs, tables and text.

In addition to the basic operations of processing, storage and report generation, many other features may be provided. These might include:

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* An average distance of 800 miles was used for the 300 station system, with Cincinnati as the Data Center.

1. Initiation of special local and remote actions when alarm signals are received.

2. Provision for remote inquiry of a random access file of information.

As an estimate of the processing time for the volume of data considered in this report, a modern high-speed computer would be able to completely process and store on magnetic tape all the data received from the 300 stations per day in approximately a half hour. The generation of the reports would, in all probability, take much longer but with a modern computer these can be generated off-line - an operation requiring access to the central computer and its associated storage files for only a small part of the total report generating time. This leaves the computer free to do other work while the reports are being prepared. An actual processing time estimate will require consideration of the particular computer to be used, the processing to be done and the amount of output to be prepared. However, assuming that the requirements used in this paper are in the ballpark of the actual requirements, a choice between scheduling the required time on a fast computer being used primarily for other tasks and use of a slower and less expensive computer would probably be considered as a first step.

Viewing the computer as a component in the overall system, the required outputs and the period over which they will be necessary is a major consideration. This will permit planning such important functions as the organization of the data file, programming of the machine, format of the remote station data. With this done, many important subsequent considerations can be begun. Typical among these is the size and cost of the data file. Assuming magnetic tapes storing 200 characters per linear inch, approximately 3 days' data from 300 stations could be stored on one 2400 foot reel of tape. Over a period of years a considerable number of magnetic tapes would be accumulated. Where long storage periods are not necessary, a carefully planned program of partial storage and reuse of the tapes would reduce the store. The tape storage estimate assumed storage of data in binary form. Other types of storage frequently used, such as binary coded decimals, may require as much as three times the number of tapes to store the same data. There are many other considerations which could be discussed but to remain within the time limit a few general comments on planning may be more useful.

PLANNING CONSIDERATIONS

Establishment of the system requirements is basic to good system planning. The requirements used in this paper were assumed from a very brief examination of the problem. Assuming they represent the magnitude of the data to be handled, the following planning considerations are in order:

1. The technical problems in implementing the system are relatively simple - therefore the system should be planned to take full advantage of the reliability, ease of operation, maintenance and economy of using relatively simple hardware.

2. The ultimate system will be gradually built over a period of time - therefore it should be designed so that it will provide maximum usefulness in its various stages of completion. For example, the installation of punched paper tape at each station prior to installation of data transmission would permit collecting each day's data and mailing them to a Data Center. There, computer time could be scheduled for automatic data processing and report writing.

3. The individual component operational specifications should be set so that they will be usable in the system with a minimum modification. Sensing elements provide a good example. The electrical output of all sensing elements should be specified to be the same even though the elements themselves may operate on widely diverse physical principles. Further, a means for electrical calibration with standard calibration signals should be specified. From the mechanical point of view the type of connector and output connections should be specified. This approach will permit direct interchange in any part of the system of different type sensing elements made by different manufacturers.

This approach generally requires prodigious effort to carry through with the end result justifying the effort.

4. By building up the partial system with components to be used in the ultimate system,

the extensive testing and administrative experience gained from operation and tests of the partial system will be directly useful in operating the ultimate system.

SUMMARY AND CONCLUSION

To introduce the systems concept a typical system was discussed and system planning considerations to gain the maximum advantage of automation, both while the system was being built up and from the completed system, were presented. Transmitting the data from remote stations in daily batches to reduce transmission line costs and the use of mailed punched paper tapes for automatic data reduction and report generation at a service center during the period before the installation of the transmission subsystem or data center were presented to illustrate the systems approach.

From this brief first look, automated methods should prove technically and economically advantageous in water quality measurements.

METHODS OF DATA TRANSMISSION

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SYNOPSIS

Definition of terms is provided and an effort is made to sort out the types of systems which are more readily adaptable to the sanitary field than the more exotic types which have prime usefulness in the missile or space exploration programs.

Telemetering systems for use in this field are classified in accordance with the A.I.E.E. Conference on Telemetering, and include current, voltage, frequency, position and impulse types. Elementary diagrams are shown with a simple explanation of each type of system along with its advantages and limitations. The time-duration impulse type is discussed at considerable length as being more adaptable to situations encountered in the sanitary field.

Transmission circuits such as private or leased telephone lines, carrier and radio are described and the advantages of limitations of each kind are pointed out. Since lines leased from public telephone facilities are more prevalent; their characteristics, limitations and rental charges are briefly described along with the selection of equipment more suitable to the particular problem at hand. The use of multiplexing arrangements is described and mention is made of the equipment available for use with such systems. Transitorized audio-frequency tone equipment in the frequency range from 400 to 3000 cycles per second is described as are systems which involve time-sharing and programming.

The selection of terminal equipment is discussed along with the choice of instrumentation and brief mention is made of the use of data readout involving punched cards or tape, magnetic tape and printing typewriter readout devices. It is pointed out that a large selection of hardware is available to operate in conjunction with essentially all forms of primary detection equipment which are currently available or which may be made available in the future. The equipment on the market today can be readily adapted to all forms of readout and data processing which may be contemplated.

DEFINITION OF TERMS

The transmission of data usually involves some form of telemetering. Within the limits of this discussion, the term "data" designates such physical or chemical values which are used and useful in the monitoring, regulating and administering of political or geographical areas in the public interest of health and welfare. By definition the "measurand" is the physical or chemical quantity to be transmitted. Telemetering involves the conversion, where necessary, of the measurand into suitable form or state for transmission over some distance and reading out the measurement, in the desired form, at the receiving or terminal end.

The element of distance may be from a few feet to several hundred miles. Within the sense which we are here concerned, electrical means are most prevalent and we shall limit our further remarks to electrical methods and types of equipment. The equipment or facilities which are required for telemetering a given function are shown in block diagram form in Figure 94. They consist of a sensing means, a means to convert or transform the measurand into a suitable form for transmission, the transmitter, the transmission medium, a receiver, a convertor to transform the input signal into a mechanical motion, a recorder or other means for registration or storage. The elements at the transmission and receiving ends are often combined into single instruments.

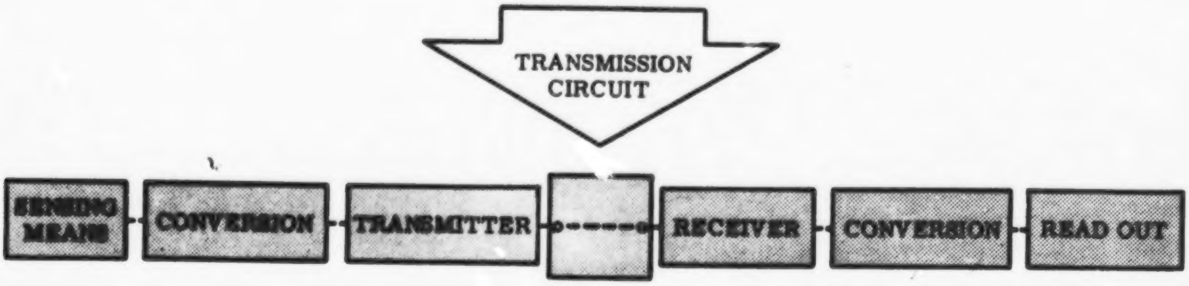

Figure 94. BLOCK DIAGRAM OF TYPICAL TELEMETERING CHANNEL.

Quantities to be transmitted may involve physical characteristics such as temperature, flow, level, pressure, turbidity or conductivity and chemical quantities such as pH, oxidation-reduction potential, chlorine residual, dissolved oxygen, etc.

MEANS AVAILABLE FOR TRANSMISSION

The following classifications are made of telemetering systems on the basis of the electrical value which is actually sent out over the connecting circuits (column 1):

Method	Medium
1. Current	Metallic
2. Voltage	Metallic
3. Frequency	All
4. Position or phase	Metallic
5. Discrete impulse	All types *
6. Pulse code	
a. Polarized code	Metallic *
b. Pulse width	All *
c. Time duration impulse	All *

* May be multiplexed using tone modulation.

Some of these systems have limitations depending upon the transmission medium which is used on a particular installation and whether two or more variables are to be transmitted over a common circuit. The classification of telemetering systems is patterned after the A.I.E.E. Conference on Telemetering, but has been modified to bring emphasis on special forms under the classification listed in Item 5.

CURRENT TRANSMISSION

Current methods, as the name implies, involves the translation of the quantity to be measured into an electric current proportional to that variable. Figure 95 shows, in elementary form a system in which a variable resistance or rheostat whose movable pointer is positioned by the variable is used to generate the current. Rheostats have inherent friction and a certain amount of power is required to position them. This reflects back on the moving element of the delicate measuring instrument

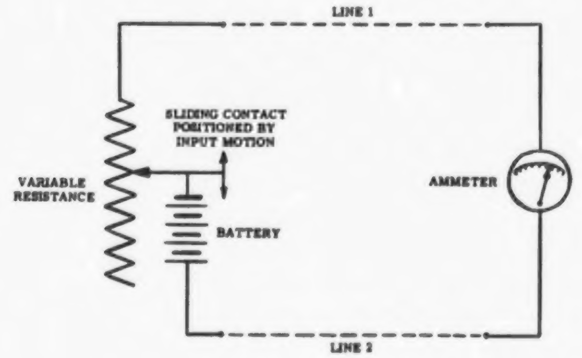
LINE 1
SLIDING CONTACT POSITIONED BY INPUT MOTION
VARIABLE RESISTANCE
AMMETER
BATTERY
LINE 2

Figure 95. ELEMENTARY DIAGRAM CURRENT TELEMETERING SYSTEM.

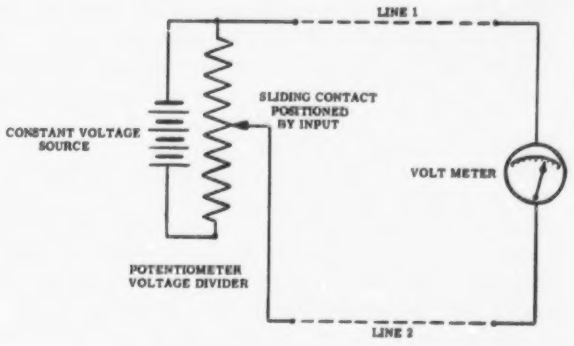
LINE 1
SLIDING CONTACT POSITIONED BY INPUT
CONSTANT VOLTAGE SOURCE
VOLT METER
POTENTIOMETER VOLTAGE DIVIDER
LINE 2

Figure 96. ELEMENTARY DIAGRAM VOLTAGE TELEMETERING SYSTEM.

causing error which usually cannot be tolerated. To overcome this disadvantage, servomechanisms are available which take little or no power from the source and multiply or amplify the force required to position the movable pointer of the rheostat. The classical current system described has an inherent disadvantage in that it is susceptible to variations in line quality.

Recent developments employ a null-balance system in which the receiver and transmitter are in series connection with the loop transmission circuit and line resistance variations are automatically compensated for. The transmitter and receiver take the form of null-balance units and at the balance point very little power is required from the measuring instrument. Ample power is available at the receiving instrument to position pen arms, actuate integrator mechanisms, etc. The current system has a further disadvantage in that it cannot be employed directly for simultaneous multiple transmission over single channels which is discussed later under "Multiplexing".

VOLTAGE TRANSMISSION

Voltage systems place a magnitude which is proportional to the measurand directly on the transmission circuit. Figure 96 outlines the voltage system in its elementary form. Here the variable resistor is replaced by a voltage divider or potentiometer with a constant voltage source impressed across its terminals and the movable contact picks off a voltage which is proportional to the total voltage for transmission. If the resistance of the transmitter and the receiver are large as compared to the resistance in the line small variations in line resistance will have little effect upon the transmission. Such a system requires frequent calibration in order to keep it in adjustment. Servo-powered recorders are used at the receiving end when necessary to get recording readout and/or to position totalizer or integrating mechanisms.

FREQUENCY TELEMETERING

Frequency telemetering systems use a sinusoidal wave form such as that produced by a two-pole alternator driven by a rotary power unit whose speed is proportional to the measured variable. An elementary diagram of the system is shown in Figure 97. The

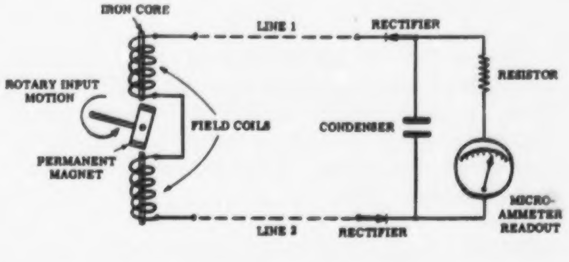
IRON CORE
LINE 1
RECTIFIER
RESISTOR
ROTARY INPUT MOTION
FIELD COILS
CONDENSER
PERMANENT MAGNET
MICRO-AMMETER READOUT
LINE 2
RECTIFIER

Figure 97. VARIABLE FREQUENCY TRANSMISSION SYSTEM.

frequency method has ideal transmission characteristics in that the characteristics of the circuit itself do not substantially change the information form. It has the advantage that it may be impressed upon a transmission circuit along with other telemetering, control or even voice channels.

A disadvantage is that rotary motion is necessary to produce the sinusoidal wave form. With the exception of the current or velocity type meter for measuring flow no other device used for sensing the measurand can be employed without an intermediate step. This increases the complication and each additional step incorporated introduces an error. New developments (2) (3) in the field of electronics have eliminated some of the past objections and it is possible to transduce position, current or voltage into frequency for remote transmission.

A further problem is occasioned at the receiving end to provide simple and accurate readout with sufficient mechanical power to position pen potentiometer and totalizer mechanisms.

For applications such as missile work these telemetering forms lend themselves readily to the monitoring of numerous functions and enable them to be in a form which can be multiplexed along with other information in a package of low weight. For permanent installations, particularly where the transmitter element is remotely located, electronic circuitry poses a problem of maintenance, service and reliability. Therefore, such systems are not extensively used for data transmission in the field here under discussion.

POSITION OR PHASE ANGLE SYSTEMS

Position systems of various designs have been used successfully for many years. Figure 98 shows a simple induction telemetering system for use over relatively short distances. Figure 99 shows a similar arrangement employing a typical impedance bridge balancing potentiometer and electronic unbalance detector which has greater resolution and can be used over greater distances. Because of the greater number of wires and limits on transmission distance, the position system is little used for in-plant service.

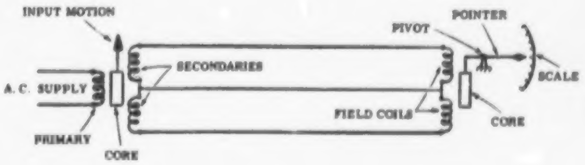

Figure 98. INDUCTIVE SYSTEM

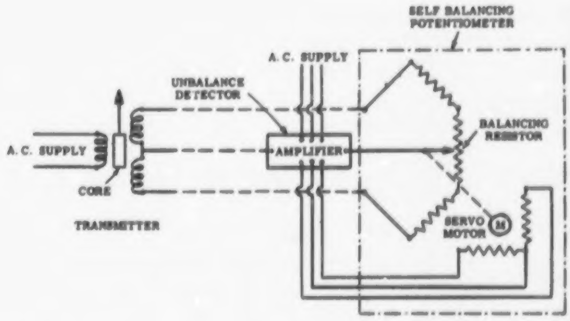

Figure 99. IMPEDENCE BRIDGE SYSTEM (WITH SERVO READOUT).

IMPULSE TELEMETERING

The impulse (or pulse) system is similar to the frequency system with the exception that the wave forms produced are of the "square" type and may or may not be uniformly spaced. The pulse system has several forms, for example; it may produce a pulse for each unit of the measurand, that is, one pulse per hundred gallons or per 100 cubic feet of flow. On other systems the interval between impulses may be proportional to the measurand, and still others establish a code similar to that used on the Bell telephone system employing a number of pulses, each of the same magnitude varying in duration or through the use of positive and negative electrical potentials which, in turn, will be recognized and read out by the receiving equipment. Figure 100 indicates an elementary arrangement of a pulse system.

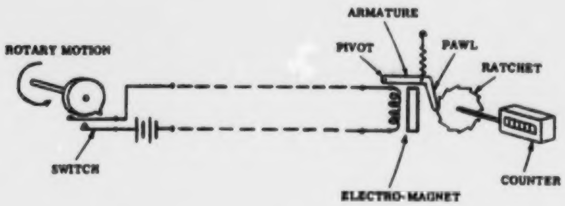

Figure 100. PULSE TRANSMISSION SYSTEM (ELEMENTARY).

The pulse system, like the frequency system, is not affected by line circuit characteristics and may be used over lower grade transmission circuits than the frequency and other type systems previously discussed. It has a further advantage in that it is quite simply multiplexed with other information channels.

TIME-DURATION IMPULSE TELEMETER

The time-impulse system or time-duration impulse (4) (5) is one of the more popular systems utilized for data transmission in the field under discussion. This is a form of impulse transmission, which because of its universal adaptability, has been set up as a separate category. It is shown schematically, in its elementary conception, in Figure 101.

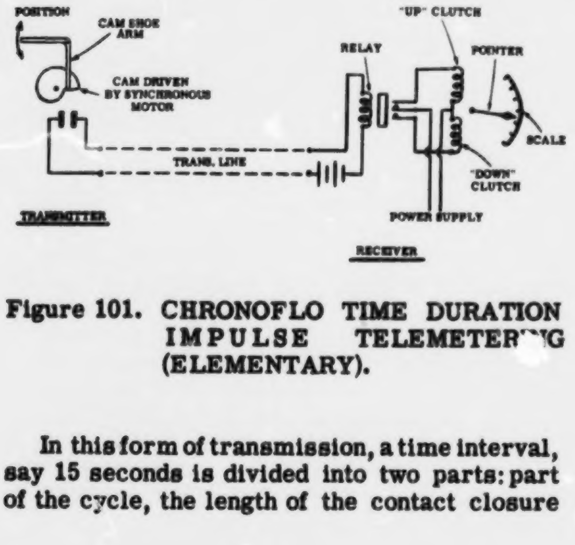

Figure 101. CHRONOFLO TIME DURATION IMPULSE TELEMETERING (ELEMENTARY).

In this form of transmission, a time interval, say 15 seconds is divided into two parts: part of the cycle, the length of the contact closure (or opening), is directly proportional to the measured variable and the remainder of the cycle transmits the "off" period which may or may not be used for transmission or indication of other variables. Like the straight impulse, the time-duration system is very simply adapted for multiplexing circuitry over metallic lines, carrier or micro-wave. It is not affected by power supply variations nor normal line resistance or impedance variations. Next to the discrete pulse system it is probably the most accurate of all the systems. It has a further advantage that registration will be immediately resumed following a power failure. There is no necessity for synchronizing and bringing the receiver and transmitter back into step.

The time-duration impulse system has an inherent advantage which is not ordinarily available with other systems of telemetering in that functions may be generated in the form of extracting the square root, correcting for weir and flume expotential formulae, putting information in logarithmic form or other form for multiplication or division. This is accomplished simply by characterizing the transmitter cam so that the signal is transmitted in linear form.

METHOD MOST APPLICABLE

The method most applicable to a particular case depends on many factors. One of these is the transmission medium. The telemetering circuit or channel available to do a given job may be one of three types:

1a. Leased or private metallic telephone lines.

b. Phantom ghost or composited circuit derived from metallic circuits.

2. Carrier or "wired wireless" on telephone, telegraph or power lines.

3. Radio or micro-wave.

PRIVATE OR LEASED TELEPHONE LINES

When metallic circuits are used, the amount of power, which can be safely handled over the circuit without damage to adjacent or companion facilities or rendering undue hazard to maintenance personnel, is limited. The

A. T. & T. Company, (6) for example, limits its maximum signal level to 270 volts, DC, and 120 volts, AC, between any conductor and ground. The maximum line current, whether AC or DC, is limited to 350 milliamps. Circuits operating with potentials over 60 volts require circuit protection in the form of 1 amp fuses. Where DC is being transmitted over the circuit, the resistance of the entire loop limits the distance with which a signal can be transmitted. Usually, this upper limit is somewhere in the neighborhood of 3000 ohms including internal instrument resistance. If AC transmission is used the impedance of the circuit increases as the frequency increases. For AC transmission at commercial power frequencies, there is very little difference in the loop resistance over DC. At higher frequency levels line losses may seriously limit the transmission distance.

Telephone companies have several types of signal channels available:

1. voice grade
2. teletype writer grade
3. low-speed telegraph grade

Voice grade circuits have a low limit cutoff of about 400 cycles per second and a high limit cutoff of about 1500 cycles per second. Voice grade circuits with special qualities are also available with an upper cutoff limit of about 3000 cycles per second frequency. For single channel transmission, the voice grade circuit is of little value; however, where multiple channel operation is required, a large number of telemetering functions can be multiplexed on to a single circuit by the use of audio-frequency tone units.

Teletype writer grade circuits are defined in word speeds of transmission and are equivalent to a transmission capability of a fundamental frequency of 23, 28 or 36 cycles per second. This represents the number of times that the circuit may open and close separately within the specified time.

Slow speed telegraph and control channels are suitable to transmit signals for a repeatitive rate up to 15 events per second. Rates for leased telephone lines vary from about $3.00 per month per mile for voice grade circuits to $0.75 per month per mile for slow-speed telegraph and telephone circuits. These changes may vary with location and also with many other complex factors, such as, number of telephone exchanges which may be involved.

The loss in power level of the transmitted signal over a pair of wires is termed "attenuation". This attenuation is measured in decibels. One decibel, as used in the telemetering sense, is equivalent to a loss or gain of one milliwatt or 1.7 millivolts working into a 600 ohm resistor at a 1000 cps.

CARRIER TRANSMISSION

The second class of transmission channel is carrier or "wired wireless". This latter name is derived from the fact that the information is impressed on metallic circuits which are carrying other functions such as power. The transmission and receiving equipment contains radio-like components which, if of the proper frequency and if connected to antenna systems, could just as well be used for transmission over the ether as well as wires. Carrier systems are primarily useful in the power field where information is required concerning power levels, switch gear positions, etc., and where private or leased telephone circuits are not available. Carrier systems on power lines have little usefulness in the sanitary field except under emergency conditions when no other transmission form is available. The carrier has the advantage that telemetering can be carried on simultaneously along with voice transmission and control systems, without mutual interference between the several functions.

RADIO TRANSMISSION

Micro-wave transmission is a special form of radio transmission in which the basic station frequency is modulated by the telemetered signal. The transmitter may be keyed by a form of information which can cause a contact closure or which can be used to vary the frequency in an oscillator circuit. Micro-wave as used for telemetering is usually directional in that its transmission is usually "focused" on the receiving antenna at the distant point. These antennae appear as open-mesh dishpans mounted on buildings or high poles. As a general rule, micro-wave transmission is limited to "line of sight" insofar as dependable transmission distance is concerned. Where longer distances are required the use of repeater stations may be required. Micro-wave transmission equipment is fairly expensive and requires at least one employee on the payroll who is licensed by the F.C.C. to operate and maintain the station. Under special situations, VHF (very high frequency) or UHF (ultra high frequency) may also be used. For practical purposes, these are limited to transmission distances up to 25 or 30 miles depending upon the amount of power used at the transmitter. There is also a citizen's band available operating in two frequency ranges in the radio spectrum. One of these is the 27 megacycle band. Power is limited and maximum transmission distance is about 5 miles. Operation on the citizen's band requires only that a third class license be available to maintain station and it is not necessary that he be an employee of the owner.

As a rule, radio is employed where no other form of transmission is available or suitable. It is usually used for point-to-point communication. Where a large number of functions are to be transmitted over a given channel, it is necessary that the information must be collected at one point for transmission. It has been used for transmission of information such as rain fall, snow fall and emergency conditions on a water shed. In such cases, the transmitter either comes into operation on a time basis or is energized when rain fall starts or flooding reaches a predetermined elevation. These systems usually operate on storage battery power and are for special situations.

In adapting telemetering to the sanitary field a number of problems must be given consideration. An important one is that of end use to which the information is to be put and whether the information is desired on a continuous basis, on an intermittent basis or on a "demand" basis.

The telemetering systems previously described are adaptable to all three types of transmission. The intermittent system is arranged so that either the transmitter comes on on a time basis or each channel is given its opportunity to come through and be read out at the receiving end.

Equipment operating on a "demand" basis is usually of a special nature. In this case the central station attendant sends an impulse or selection code out to the transmitting end where a relay is closed causing the transmitter to begin sending for several cycles of operation until the receiver has time to come into step with the transmitter and the information to be read out or recorded. Overriding alarm features may be used on the intermittent and "demand" systems. In this case, an impulse is transmitted automatically from the transmission end whenever the measured variable or some related function exceeds some predetermined value. For example, in monitoring the output from a pumping station, a bearing temperature thermometer may actuate a relay to send a signal over the circuit to call the operator's attention to a hot bearing.

MULTIPLEXING

Throughout this discussion, we have mentioned the multiplexing of telemetered information.

In many cases the information to be transmitted is numerous and it is not economical to employ separate circuits. In such cases it is quite feasible and practical to transmit the information over a single circuit or channel. Where two functions are to be transmitted special equipment is available which permits both functions to be sent in simultaneously without mutual interference. The arrangement is shown schematically in Figure 102.

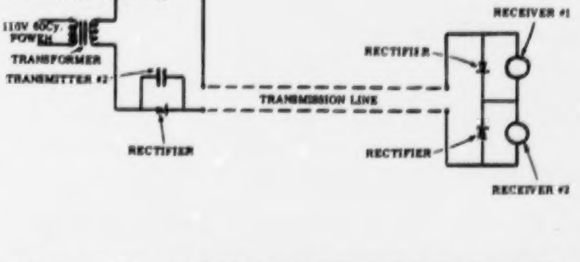

Figure 102. TYPICAL METHOD FOR TRANSMISSION OF TWO SIMULTANEOUS FUNCTIONS.

Power is supplied by commercial AC sources and the rectifiers are so polarized that one set of the telemetering equipment operates on the positive half wave and the other on the negative half wave of the cycle. The rectifiers act as gates to permit the impulse to go into the proper units and there is no mutual interference.

Circuits can be devised which permit simultaneous transmission of two variables over a single pair of wires employing a ground return. This is to be avoided, wherever practical, as there is greater hazard in this condition from natural causes on this type of circuit. Extreme precautions must be taken to prevent damage to the terminal equipment.

Where two or more functions are required over the same circuit they are sometimes transmitted on a time-sharing or sequencing principle. This system operates on the basis of connecting a given transmitter and its respective receiver to the transmission circuit or channel for a short period so that a fresh read out can be obtained. A second transmitter and receiver is then connected to the circuit and so on, in sequence, one after the other, until a complete cycle or scanning of all the units has been completed. This involves perfect synchronization of the switching equipment at each end and is usually carried out by sending a synchronizing signal after each cycle of transmission. Special precaution has to be taken upon loss of power at one end so that equipment does not restart out of synchronization. The switching may be done mechanically employing synchronous motors or may be handled electronically. The multiplexing just described was developed in the telegraphy field, it was first applied to a municipal water system at Washington Suburban Sanitary District, Hyattsville, Maryland, in 1947. (7) Originally the sequential type of multiplexing was employed to overcome limitations imposed by the telephone companies on simultaneous use of circuits. A charge was made per channel rather than per mile a line wire on the basis of each function to be transmitted. Currently there is no limit on the number of sets of information which can be transmitted. Present telephone company regulations permit unlimited use of the channel provided there is not simultaneous telephone and telemeters involved.

Modern methods employ the use of audio-frequency tone equipment for simultaneous transmission of two or more variables. Figure 103 shows a schematic arrangement of a tone type multiplexing system. All telemetering signals are impressed on the single metallic pair, carrier or radio channel simultaneously.

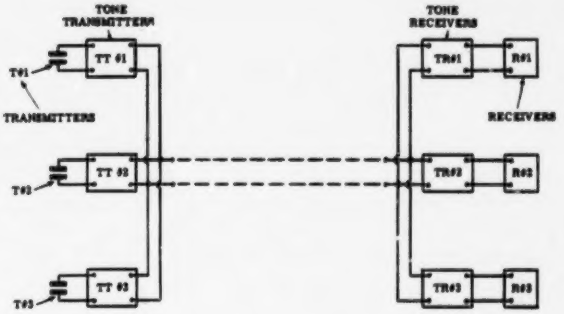

Figure 103. AUDIO FREQUENCY MULTIPLEXING SYSTEM.

The tone units have frequency generators and filters which control the frequency within narrow limits. These are usually spaced with 100 or 120 cycles per second separation between 400 and 3000 cycles per second thus permitting 22 to 26 functions to be handled simultaneously over a single circuit.

Figures 104 and 105 show typical transistorized tone equipment. Each tone rack employs

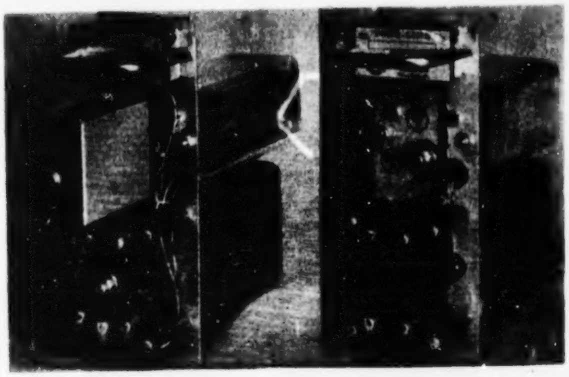

Figure 104. MODULAR TONE RECEIVER AND TRANSMITTER COMPONENTS.

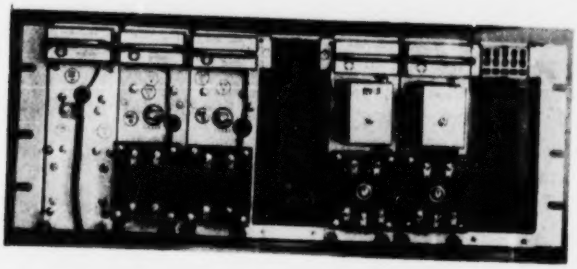

Figure 105. MOUNTING RACK WITH POWER SUPPLY FOR UP TO SIX TONE UNITS.

a common power pack and is capable of handling six receivers or six transmitters or combinations thereof. All components are of the plug-in type to permit easy maintenance and inspection. The transistorized tone transmission equipment has the advantage of economy in first cost, minimum installation space, absence of heat and long life. Vacuum tube tone equipment is also available.

TERMINAL EQUIPMENT

A great deal of equipment is available for telemetering information in the sanitary field. Careful judgment should be exercised in its selection and application in order to insure the most practical and economical system which will be suitable for a particular installation. It is insufficient to record data in a form which requires extensive modification before processing is possible. For this reason, considerable attention should be given to the final step in any particular program.

The freshness of the information telemetered as well as the end use to which it is to be put, has an important consideration in the selection of the equipment. Certain information such as air temperature may not change perceptibly over a period of several hours and, therefore, occasional sampling would be sufficient. On the other hand, temperature of a motor bearing could conceivably change to a dangerous degree in a period of a few minutes and more frequent sampling is necessary. Water levels in lakes or large rivers may not change substantially over a long period of time while those in small streams, sewers or drainage ditches may change substantially over a short period.

At the receiving end the telemetered information can be displayed on indicating, recording and/or integrating or totalizing instruments. Typical instruments for this purpose are shown in Figures 106, 107, 108, and 109. Standard devices are available for installation in the large case instruments for totalizer readout of values such as flow. Separate devices are available for panel mounting for the same purpose with the compact or miniaturized recorders. The round chart recorders have the advantage that an entire day's (or week's) record is displayed on the face of the instrument so that trends can be easily checked. The

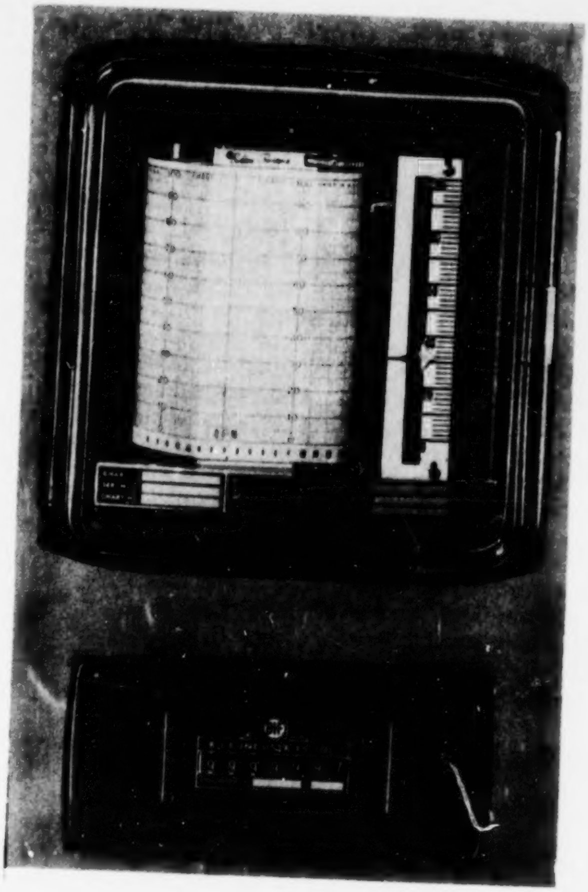

Figure 106. COMPACT 4" WIDE STRIP-CHART INDICATOR-RECORDER WITH SEPARATE PANEL MOUNTED TOTALIZER.

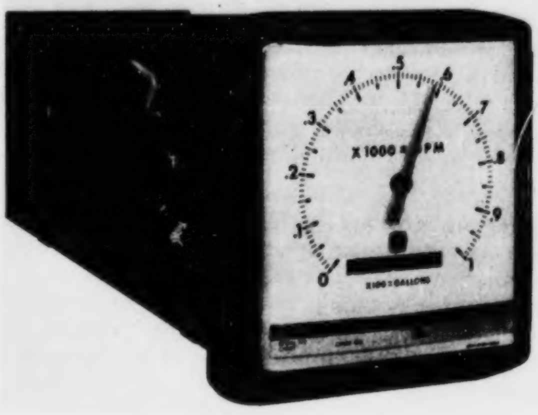

Figure 107. COMPACT INDICATOR WITH INTEGRALLY MOUNTED TOTALIZER.

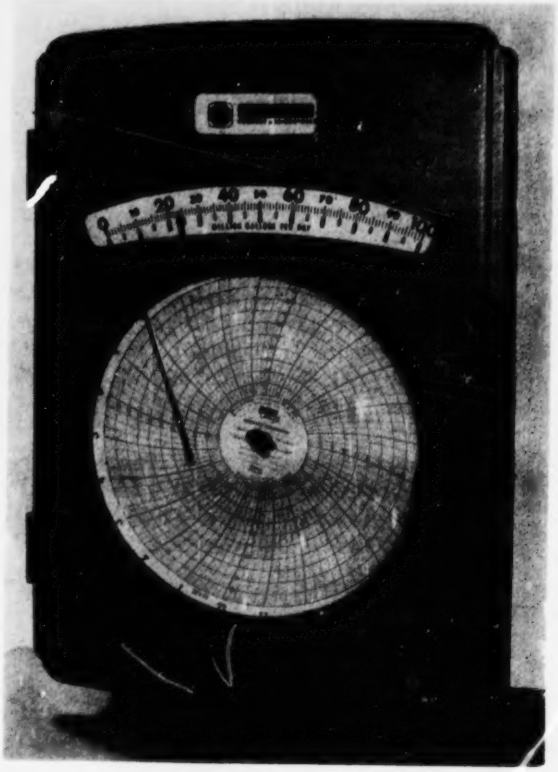

Figure 108. RECTANGULAR 12" CIRCULAR CHART RECEIVER.

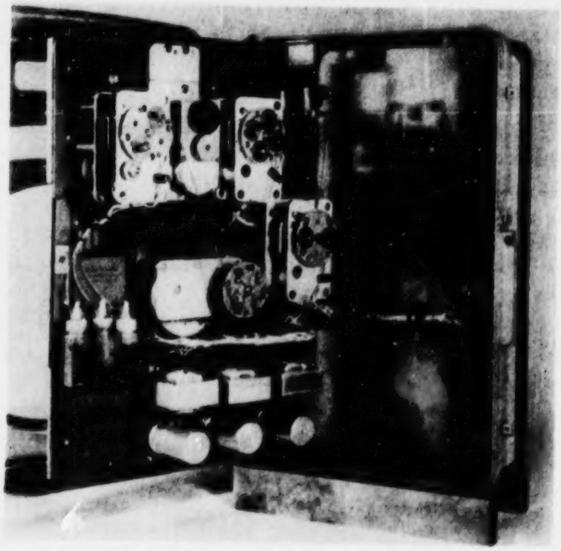

Figure 109. RECTANGULAR CASE WITH MECHANISM PLATE IN OPEN POSITION TO PERMIT ACCESS FOR MAINTENANCE.

compact or miniaturized recorders take up less panel space and are equipped with 30 day charts. In most cases a chart recorder is sufficient for most purposes. Where the data is to be further processed for storage or computation, numerous methods are available for this purpose.

The receiver instruments may be equipped with a potentiometer, mounted internally, which will provide a voltage readout at the receiving end for use with card or tape punching devices. The cards or tapes can then be stored or fed into computing machines as necessary.

The voltage readout thus obtained from the potentiometer can also be used to work with an automatic typewriter so that a log of periodic operations may be kept. A scanning or programming device is generally associated with such systems. Under this arrangement, all of the receiver units are periodically scanned and the latest reading is printed in digital fashion on a log sheet. The readout may be set up for once every fifteen minutes, thirty minutes, hourly or daily. Extra features are available such as overriding alarm functions which print out in red numerals and can be made to sound an alarm to call the station operator's attention to the malfunction or emergency condition.

Other systems are available whereby the information in the form of discrete impulses or digital codes is transmitted and local charts are omitted. This information may be used to punch cards or tapes directly and to periodically read out the data upon demand or on a time-program basis.

CONCLUSION

Telemetering equipment is available to handle all types of transmission problems which may occur in the sanitary field. Such variables as levels, temperatures, flows, pressures, pH, turbidity, dissolved oxygen, oxidation-reduction potential, chlorine residual, conductivity and many other physical and chemical properties can be transmitted to a central collecting and monitoring point for the purpose of control and administration.

Means are available to secure economy in data collection through the use of multiplexing by mechanical, audio-frequency tone, radio and carrier devices. Data storage is available in the form of chart recordings, integrators or totalizers, punch cards, magnetic or punched tapes.

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APPLICATION OF DIGITAL DATA TRANSMISSION TO WATER MONITORING DATA

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The past few years have witnessed a rapid expansion of automatic data processing systems in business, science and military. In many processes, machines have replaced human beings and this trend is continuing with ever increasing rate.

The language used in the data processing machines, is different and much simpler than the language used by the humans. While the human speech is analog in its nature, the machine language is digital and in almost all instances binary. At any instant of time, the binary language can assume only one of the two possible values - yes or no, commonly referred to in the digital data transmission field as "mark" or "space".

Just as humans must communicate over long distances between various geographical locations using speech, there is a great need for the digital machines to communicate in their own binary language. The last type of communication is referred to as the digital data transmission.

The primary objective in the digital data transmission is the lowest possible cost per bit of transmitted information. This may only be possible when the transmission time necessary for sending each bit is minimized. In turn, the minimum time for sending a bit of information implies the maximum speed. It goes without saying that the speed alone would be meaningless unless accompanied by an acceptable accuracy criterion.

The next question is what communication medium should be used for the digital data transmission? Humans communicate over the extensive voice telephone network which covers almost every geographical location in the U.S.A. Why not employ the same network for the high-speed data transmission on a similar basis except that the signals would be, of course, different from the voice signals? Indeed, the so-called common carrier telephone can serve the purpose in spite of the fact that it was designed for the voice signals. While it cannot be denied that many problems arise when digital signals are sent over the voice telephone circuits, nevertheless the obstacles can be overcome by judicious matching of the terminal equipment of the transmission medium.

With the presently available techniques, it is possible to achieve a speed of 1500 bits per second with a reasonable degree of accuracy. It is interesting to make a comparison of the high speed digital data transmission over the telephone network with the teletype system. The speed of the teletype system is 100 words per minute; this is equivalent to 75 bits per second. On the other hand the high speed data transmission system can send bits at the rate of 20 times higher than the teletype so that an amount of information which takes one hour to be transmitted over the teletype takes only three minutes over the data transmission link. Calculations indicate that on the basis of cost per bit the high speed data transmission is more economical than the teletype. Furthermore, the common carrier telephone network is much more extensive and flexible than the teletype network.

A TYPICAL DATA TRANSMISSION LINK

The data transmission systems consist of Data Transmission Links. A typical link is shown in Figure 110.

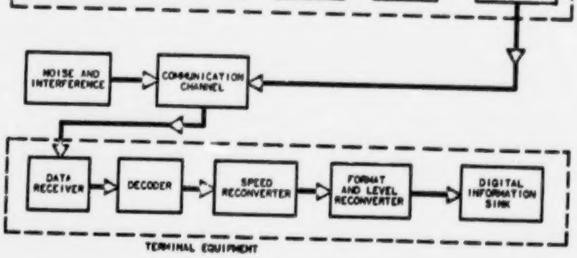

Figure 110. ELEMENTS OF THE DATA TRANSMISSION LINK.

The Digital Information Source delivers the data in binary form to the Format Converter. Usually the data source is paper tape, magnetic tape, punched cards or any other device whose output is a stream of binary digits. This stream of digits enters the Format Converter. The function of the Format Converter is to change the data levels to a form suitable for the system. In some systems, the Format Converter transforms also the binary digits from the parallel form to the serialized train of pulses.

Quite often the speed with which the data source delivers the binary digits is different from the speed of the data transmission equipment; in most cases the speed of the data transmission equipment is constant and consistent with the capabilities of the transmission medium. Because of the variety of the data sources, the speed of the data source may be lower or higher than the transmission speed. As a result, it often becomes necessary to match the two different speeds, by using either the Speed Converter or Buffer Storage equipment, depending upon the particular application. This is shown in Figure 110.

The output of the Speed Converter consists in most instances of a serialized train of binary digits which may enter the data Encoder or be fed directly to the Transmitter. If it is desired to incorporate error detection or correction into the system, then the data Encoder will insert redundant binary digits between the information digits coming from the Speed Converter. Otherwise, the data digits go directly to the Transmitter.

The pulse train at the input to the Transmitter has a constant speed which can be accommodated by the communication channel. As pointed out previously, the communication channel has been designed to handle the analog voice signals rather than the discrete digital data signals. Consequently, the transmission channel cannot handle the data signals which are in binary digital form. It becomes therefore necessary to insert a data transducer which converts the digital train of pulses into analog form suitable for transmission over the telephone lines. This transducer is depicted in Figure 110 as the Data Transmitter.

The Data Transmitter and Receiver are perhaps the most important elements in the Data Transmission Link. They must be properly matched to the transmission line to achieve the maximum speed of data digits.

The Data Transmitter is followed in Figure 110 by the receiving end of the data link. It is the function of the Data Receiver to minimize any noise and interference and to extract the digital information from the signal wave which passed through the telephone channel.

DIGITAL DATA TRANSMISSION SYSTEM FOR WATER MONITORING

Functionally speaking, the water monitoring systems on the Federal and State levels are basically similar. That is a number of data acquisition stations forms a satellite system around the center and the data collected manually at each station is sent to the Data Processing Center for analysis. This is essentially a unidirectional flow of information from outlying stations to the concentrating station for the processing of the data. Furthermore, it is assumed that in the future there may be a need for bidirectional exchange of the processed information, either between the Federal and State centers or just between the State centers.

As pointed out in the companion paper on the data processing, the volume of information flowing from a satellite station to the Data Processing Center is low, being of the order of 40,000 bits per day and requiring a transmission time of perhaps less than 3 minutes. On the other hand, it is believed that the information volume exchanged between Data Processing Centers may be relatively high. These assumptions will have to be firmed up.

Using these assumptions as a starting point and bearing in mind that the economy of the entire operation is important, it is suggested that the overall data transmission system consist of two subsystems. One subsystem would be a data acquisition and processing center, Federal or State, with satellite stations at which the data is automatically collected. The flow of information in this subsystem would be unidirectional as shown in Figure 111. Each station would transmit the data once a day at a prearranged time to the Data Processing Center. Hence the unidirectional transmission would proceed on a sequential basis from station to station.

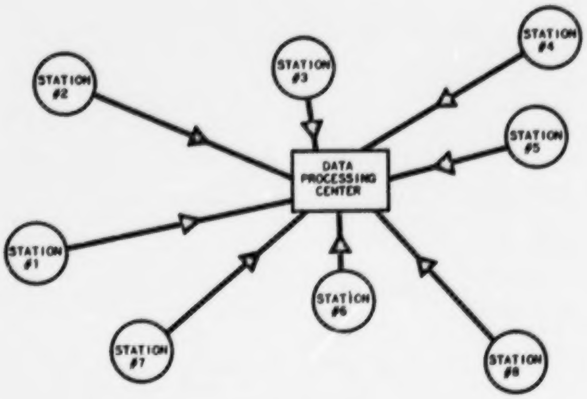

Figure 111. DATA PROCESSING CENTER AND SATELLITE STATIONS (SUBSYSTEM ONE).

In view of the relatively low volume of information at each station, the data will be sent at slow speed on the common carrier transmission medium. If so, then it is quite feasible to assume that it may be possible to use the error correction process rather than the error detection to avoid the necessity of acknowledging the data from the center and eventual retransmission. At low speeds of the order of 200 to 250 bits per second, the impulse noise on the transmission medium does not present a serious problem and its effects may be overcome by introducing self-checking error correction in the form of redundant digits. Since the speed is low the necessary amount of redundancy will be relatively small.

Capitalizing on the fact that the speed of the transmission is low and that the information flow is unidirectional, the data transmitters which will be necessary at the individual stations can be made simple and relatively inexpensive. The Data Processing Center will have one or more receivers. These will have to be more elaborate and expensive than the transmitters, since each receiver would serve many transmitters.

It is difficult at this time to say how many receivers may be needed at the Data Processing Center. This depends on the number of stations and on the statistics of possible emergency calls from the individual stations to the Data Processing Center.

It is envisioned that each station will have stored a binary word in a shift register, which will be gated repetitively for transmission in the event of an emergency at a particular station. Remembering that the stations will transmit information sequentially with perhaps a few minute intervals between the end of transmission from one station to the beginning of transmission from the next station to the Data Processing Center, it is apparent that the time intervals between regular transmissions may be utilized for the transmission and reception of the emergency signals.

As soon as an emergency indication is detected at a station, the Logic circuit will start emptying the emergency word register and at the same time will initiate a preset dialing to the Data Processing Center. In the event of a busy signal the dialing will be repeated at perhaps one minute intervals until the period between sequential transmissions from other stations permits the delivery of the brief emergency signal to the Data Processing Center. Should the Center have more than one receiver, the preset dialing will try sequentially all receivers until the connection is made.

The actual timing, the number of necessary lines and receivers will have to be determined upon more detailed statistical study of the water monitoring system.

The previous description covered the first subsystem of the digital data transmission system in which the remote stations transmit sequentially the information at slow speed to the Data Processing Center for analysis.

The function of the second subsystem of the data transmission system is to exchange the information between the Data Processing Centers. It is assumed that the volume of this information may be quite large. Whenever the information volume to be transmitted is large, the cost of the transmission medium becomes much more significant than the cost of the terminal equipment. Consequently it is mandatory to minimize the transmission time of the information to achieve the best economy of operation. Thus high speed digital data transmission of the order of 1000 to 1500 bits per second is envisioned for the exchange of the data between the Data Processing Centers.

However one immediately runs into problems when high-speed data digits are sent over the common carrier, which as pointed out previously was designed actually for the voice transmission. One of the most significant problems is the presence of the impulse noise. The effect of impulse noise is to destroy a number of consecutive binary digits so as to cause bunches of errors. Although a burst of impulse noise may mutilate a large number of digits, the frequency of occurrence of such bursts in many instances is low.

To cope with the problem of errors occurring in bunches, it is possible to use error correcting codes in the form of interleaved parity checks. There are, however, basic difficulties with such codes. First of all, the number of errors in a burst is usually large. As a result, the redundancy required is high thus reducing considerably the effective speed of transmission. Secondly, large redundancy implies sizeable and complex logical hardware in the coding and decoding equipment.

Consequently, because of the considerable speed reduction factor and the cost of hardware, it does not seem practical to utilize error correcting codes for high speed data transmission.

The picture is completely different with the error detecting codes. These codes offer a reasonable protection in systems where the retransmission or discarding of mutiliated information appears feasible.

Considering the fact that the second subsystem will have bidirectional transmission, retransmission of the mutilated information will not be a problem in the event of errors which may be detected at the receiving end of the data link. In order to optimize the system it is desirable that the number of the retransmissions be as small as possible. This will be calculated from the available data on the noise conditions, such as the time distribution between the noise bursts, the practicable speed of transmission and the optimum block length of the binary digits.

The subsystem encompassing the Data Processing Centers is shown in Figure 112. Each Center will have probably most of the equipment shown in a typical data transmission link, Figure 110. Since the information will flow in both directions, a typical Center will have to be equipped for transmission and reception. This will be in addition to the slow speed data receiver at each Center for the reception of unidirectional information from the outlying Satellite Stations.

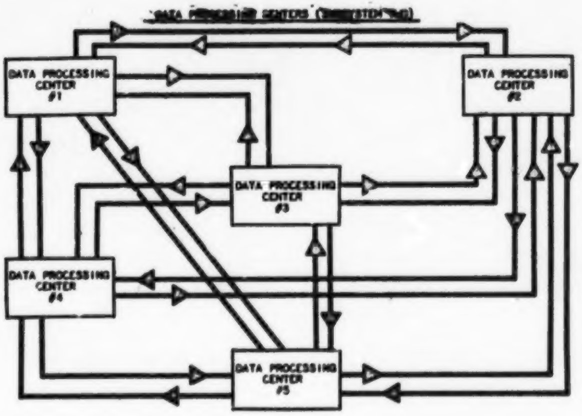
DATA PROCESSING CENTERS (SUBSYSTEM TWO)
DATA PROCESSING CENTER #1
DATA PROCESSING CENTER #2
DATA PROCESSING CENTER #3
DATA PROCESSING CENTER #4
DATA PROCESSING CENTER #5

Figure 112. DATA PROCESSING CENTERS (SUBSYSTEM TWO).

Figure 113 shows a Satellite Station. The binary information representing the result of the water monitoring over a 24-hour period is processed through the Logic stage for transmission. The primary function of the Logic, which is regulated by the Control, is to gate the information digits at a predetermined time to the slow speed Data Transmission Equipment in Figure 113. In the case of an emergency, the Stored Word Register is energized and at the same time the Logic will inhibit the flow of binary information, if any, gating the Stored Word to the Data Transmission Equipment.

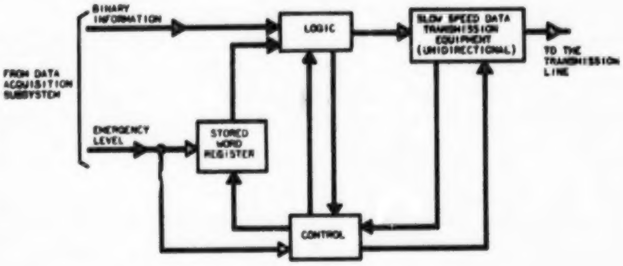
BINARY INFORMATION
LOGIC
SLOW SPEED DATA TRANSMISSION EQUIPMENT (UNIDIRECTIONAL)
TO THE TRANSMISSION LINE
FROM DATA ACQUISITION SUBSYSTEM
EMERGENCY LEVEL
STORED WORD REGISTER
CONTROL

Figure 113. SATELLITE STATION

The heart of the station equipment is the Control. The Control regulates the proper timing of the information flow; it recognizes the emergency, it initiates the repetitive preset dialing and synchronizes the operation of all other units. The Slow Speed Data Transmission Equipment is capable only of transmission and may have some of the elements of a typical data transmission link shown previously in Figure 110. The entire operation at the Satellite Station is unattended except for periodic maintenance.

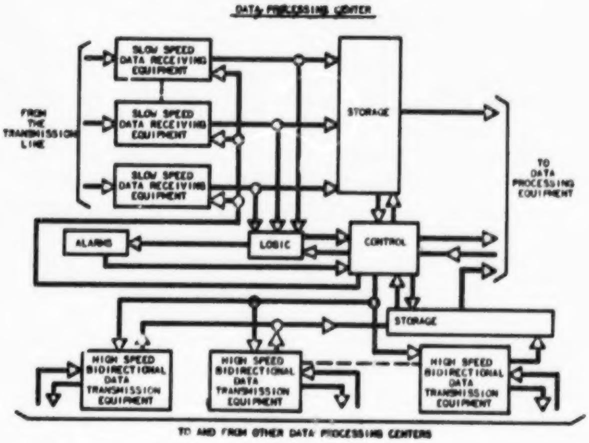
DATA PROCESSING CENTER
SLOW SPEED DATA RECEIVING EQUIPMENT
SLOW SPEED DATA RECEIVING EQUIPMENT
SLOW SPEED DATA RECEIVING EQUIPMENT
FROM THE TRANSMISSION LINE
STORAGE
TO DATA PROCESSING EQUIPMENT
ALARMS
LOGIC
CONTROL
STORAGE
HIGH SPEED BIDIRECTIONAL DATA TRANSMISSION EQUIPMENT
HIGH SPEED BIDIRECTIONAL DATA TRANSMISSION EQUIPMENT
HIGH SPEED BIDIRECTIONAL DATA TRANSMISSION EQUIPMENT
TO AND FROM OTHER DATA PROCESSING CENTERS

Figure 114. DATA PROCESSING CENTER.

A typical Data Processing Center is shown in Figure 114. The top of the Figure depicts the Slow Speed Data Receiving Equipment which receives information on a sequential basis from the satellite stations. This information is placed in the Storage medium for further processing. Any emergency indication will be recognized by the logic which in turn will trigger the Alarm circuit.

The high speed data information which is exchanged with other similar Centers is processed through the high speed bidirectional data transmission equipment shown at the bottom of Figure 114. Again the Storage serves as a buffer stage between the Data Transmission Unit and the Data Processing Equipment. All timing and the control over the flow of the information is performed by the Control. However the Data Processing Center is operated on attended rather than the unattended basis. As a result the dialing functions between the Centers may be performed by the human operators.

It is assumed that the equipment both at the Stations and at the Centers will be standardized and will consist of building blocks such as shown in Figures 113 and 114. This will permit to make provisions for growth and expansion. Clearly, for the individual Stations, the equipment will be always the same regardless of their number and rate of growth. On the other hand the expansion of the system will require more slow and perhaps high speed Data Transmission Equipment units at the Data Processing Centers. In addition some other units such as shown in Figure 114 will require modifications. It is important that they are designed in such a manner that only a minimum number of changes is required when the system expands and has to adapt itself to the new conditions.

TRANSMISSION MEDIUM, MODULATION AND ERROR CONTROL

The successful operation of the entire data transmission system will depend to a large extent upon the design of the terminal equipment; the transmission medium is a fixed element in the overall system and the designer has little control over the communication channel. Thus the characteristics of the communication channel must be well known and understood so that the terminals are properly tailored to the transmission medium. It is felt that it would be of value to present briefly some of the available techniques used in the design of terminals, particularly in the field of the digital modulation and error control.

Before this is done it is in order to review certain salient characteristics of the communication channel which have bearing on the speed and the accuracy of data.

As previously pointed out, the voice communication channels were essentially designed for the transmission of voice. Consequently, little attention was paid to the factors significantly affecting the transmission of high speed digital data which contains relatively little redundancy compared to the voice signals. One of the key factors in the digital data transmission is the amount of departure from the linear phase in the characteristics of the communication channel. This amount of departure from linearity determines in effect the available bandwidth of the channel. In turn the available bandwidth determines the maximum possible speed of transmission. The greater the departures from the phase linearity, the lower the speed of transmission.

The effect of the differential phase on data regardless of the modulation method is to stretch out the individual binary digits in time so that the neighboring digits begin to interfere with each other and the recognition of the individual bits at the receiver becomes difficult. One obvious remedy is to lower the speed of transmission. This results in a higher cost per bit. Another remedy is to equalize the terminals or to subdivide the voice channel into many narrow channels. The last one however, leads to an increased complexity and cost of the terminal equipment as well as to some waste of the bandwidth because of the necessity of providing guard bands between the individual channels.

The communication channel is essentially a bandpass filter and is not capable of accommodating the data in the form of binary on-off digits. As a result carrier modulation becomes necessary so that the yes-no digits are represented on the transmission medium at any instant of time by one of the two distinct states of the carrier. These two states may be two different amplitudes of the carrier or two distinct frequencies or two phases of the carrier. It is also possible to have any combinations of the above.

The objective of the demodulation process at the receiving end of a data transmission link is to recognize at discrete instants of time the state of the modulated carrier so it may be uniquely determined whether this state is yes or no binary digit. There are a number of known techniques used in the demodulation stage such as envelope detection, product detection, correlation detection, zero crossing detection and others. Which technique is to be used for a given data transmission system, depends upon the particular application. Some of the factors that must be taken into the consideration are the speed, the desired degree of the accuracy and the relative costs of the communication channel and the terminal equipment.

One of the most effective methods to assure the desired accuracy is to provide error correction or detection for the binary stream of information digits. While the error correction seems to be feasible for low speed data, it appears that for the high speed data links the error detection and retransmission is more effective than the error correction. In view of the multiple errors occurring at the high speeds the amount of redundancy and consequently the amount and the complexity of the equipment for error correction would be prohibitive.

In order to illustrate the difference in the redundancy requirement for the error detection and correction, a simple example of single error detection and correction will be presented. Before this is done, a more general concept of error codes will be discussed. This concept is based on a geometrical model *. One may visualize a symmetrical solid with many vertices, each vertex representing uniquely one combination of n binary digits. Inasmuch as n binary digits permit 2^n distinct combinations, the total number of vertices is 2^n. Each vertex may represent one letter in the alphabet used for the transmission of information. Suppose now one binary digit in a particular letter is altered by noise. If so, then the erroneous letter will resemble exactly one of the neighboring vertices representing another letter. It is clear that if all vertices are used in the alphabet, it is not possible to recognize any errors at the receiver. However if only some vertices or combinations are used and other combinations are forbidden it is possible to detect or correct errors. Suppose the alphabet consists of letters such that any two letters would differ in at least two binary places. Then, if a single error occurred, it could be easily detected. If any two letters differed in three binary places, single error correction would be possible.

Figure 115 shows an example of error correction in the case of two letters having a

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* R. W. Hamming--"Error Detecting and Error Correcting Codes" B.S.T.J. April 1950

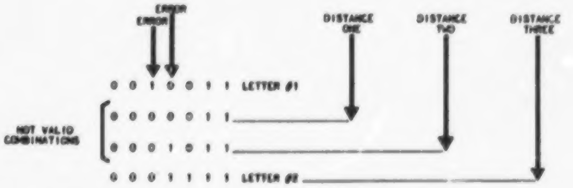

Figure 115. EXAMPLE OF ERROR CORRECTION AND DETECTION.

distance of three. The distance between any two binary letters is defined as the total number of binary places in which the two letters differ. It may be seen from Figure 115 that for the particular case chosen a single error can be corrected and a double error may be detected but not corrected. A triple error cannot be either detected or corrected.

In general, the maximum number of errors that may be corrected or detected bears the following relationship to the minimum required distance between the letters of any binary alphabet:

$$\text{Errors corrected} = \frac{D - 1}{2}$$

$$\text{Errors detected} = D - 1$$

where D = minimum distance between any two letters.

While the above concepts are useful in illustrating the basic foundation of the error control, a more practical point of view rests on the concept of redundancy.

The simplest form of the redundancy is a single parity check. The binary message is divided into blocks. An extra digit is added to each block to make the total of binary one's either odd or even. This is commonly referred to as an odd or even parity check. In the event of a single error in any of the blocks, the receiver detects the error by counting the number of binary one's.

Clearly, the extra parity check digit in each block carries no information and represents the redundancy. If it is desired to detect multiple errors in a block of digits, more redundancy must be added in the form of parity check digits.

The following example illustrates the relative redundancy requirements for the simple case of blocks consisting of four binary information digits. To avoid ambiguities, the redundancy is defined as the ratio of the check digits multiplied by one hundred to the total number of digits in the block.

For the single error detection only one parity check digit is necessary for the four information digits so that the redundancy is 20%. The single error correction will require three check digits for four information digits so that the redundancy of the single error correction is 43%.

The number of check digits necessary for the four information digits in the case of single error correction was determined as follows.

Let the number of the check digits be represented by $\underline{k}$. A total of $\underline{k}$ binary digits will provide a check for $2^k - 1$ binary places, since the all-zero sequence cannot be utilized. Now the total number of binary places is $m + k$, where m represents the number of information digits, which is four in this particular case. Thus

$$m + k = 2^k - 1$$

and $m = 4$, therefore $k = 3$.

As the length of the block increases, the amount of redundancy for the error detection or correction tends to decrease. The basic limitations however on the length of the block are the amount and complexity of the equipment which goes up exponentially with the increased block length. The noise distribution also imposes restrictions on the maximum block length.

CONCLUSIONS

The system outlined in this paper was presented primarily to illustrate the salient characteristics and possible application of the digital data transmission to water monitoring.

The growth figures for the water monitoring system indicate that the data transmission may become economical and desirable in the not-too-distant future. It is felt therefore, that a more detailed study and perhaps an experimental set-up on a limited basis may be warranted at the present time to provide a basis for the future data transmission system.

A NEW MEDIUM FOR LOW COST RECORDING

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After listening to the papers that we have heard here and papers given at similar symposiums, it is difficult not to come to the conclusion that shortly we are going to be surrounded by machines for the various jobs with which we are all concerned. Surrounded, I think, in a few years to the point where we will be up to our necks in them, or at least this is the impression that you can easily get.

What I would like to discuss briefly with you this morning is a new compact recorder for digital or analog information. I would also like to cover to what uses this recorder has been put so far and what we envision at this point as the future possibilities for this device and devices of this specific nature.

First of all, as I describe what this recorder is, I would like to have you use your imagination just a bit, if you will, and imagine for a moment that you are an engineer and you have a project, and this project is to develop a recorder with some very specific capabilities. Typically, you would like to be able to drop it from reasonable distances, like 15 feet and not have it damaged. You would like to be able to get it pretty hot, let's say 75 or 80 degrees centigrade, and have nothing happen. And you would like to be able to freeze it, say down to minus 50 centigrade. You don't want it to be subject to influences from magnetic fields and you would like to have it run underwater, or let's say under conditions of 100 per cent humidity. It can't cost much, and it ought to produce a record that you can look at with your eye and determine what is on it. It ought to be permanent, that is if I look at it today I want to see the same thing that I see when I look at it two weeks or two years from now. Also, it has to be close enough to standard techniques so that most of them will apply. You can't radically deviate and say, "Well I am going to record on air molecules, and even though there is no way to get this information back I know it is there when I put it there." This has to be something you can work with.

This is about the situation which some friends of mine with our company were in. On the face of it it sounds like it might be just a little hopeless. What actually occurred was that a reasonably quick analysis of the ways that information can be recorded resulted in the conclusion that basically you can record it by either changing the state of something, by adding something or by removing something. A further analysis of the possibilities of these within the restrictions of the problem led us to conclude that if we were to take a medium which itself would survive the environmental conditions we described and then find some way to either change its state so that it was visible, or remove a portion of it so there was a difference there, a hold if you will, this might satisfy the requirements. And this ultimately led to the--invention is perhaps not the word --let's say to the creation of digitape. This is, basically, a Mylar medium, transparent, to which is applied a very, very thin coating of aluminum. Then to record data, this aluminum is evaporated at points and in a pattern which is required to give you essentially clear windows through this mirror of aluminum.

And it does meet the requirements that I have outlined if you will think back over them. First of all, it is in terms of the environmental conditions that it will stand, quite rugged, quite strong, and time has very little effect on it other than to sometimes dull the aluminum slightly. Magnetic fields have no effect. You can look at it and see the information on it that you are trying to read. And it has some advantages beyond these which are quite significant. Very dense packing is possible, you can get a lot of information in a square inch of material, and you can record this information with the material either stationary or in motion. Also, in getting the information back it is possible to read this back either with the material stationary or in motion.

The obvious comparisons here are with paper tape and the magnetic tape. I would say paper tape is the closest physical parallel.

In this case you are actually creating a hole in the paper by taking some paper away, and it is very similar to the method of creating a window in the digitape. Digitape packing densities are much greater than paper tape however. For example, common one-inch paper would usually have eight parallel channels possible. A one inch digitape record may have as many as forty, and usually a minimum of 32 parallel channels, so that there is a factor of at least four there, and this factor, when you consider the length of the record, is squared, since the paper tape one inch long and one inch wide would have eight channels across the width and eight channels in length to give you 64, whereas digitape of the same width and length would have 32. and 32.

To look a little further into the comparison of digitape with other recording media, let's consider magnetic tape. A reasonably standard magnetic tape at the moment is one which creates two hundred bits per linear inch of tape.

This is more than we have presently been able to accomplish with this medium, but our packing densities from side to side, or across the tape, are heavier so far than magnetic tape is generally able to accomplish, and the total comparison comes out to be approximately two thousand bits per square inch of digitape as opposed to let's say a figure of 2800 bits per square inch on magnetic tape. With reading and writing capabilities of the same order of magnitude, and with the additional ability to be able to see visually what you have written, and to read or write either stopped or in motion, it would appear then that there might be some significant advantages to this recording medium, assuming now that we can actually create a recorder whose first cost is low.

The major function as we see it now, and as was originally the goal of the development process here, was to get a recorder whose mechanics were, first of all, as simple as possible, and secondly which did not require a complex electronics system in order to operate it. And this has been in a large extent accomplished. A very small voltage level, such as has been previously mentioned this morning, a contact enclosure with a very small applied voltage, is all that is necessary in this recorder to create one of these windows in the Mylar tape. The probe which creates this is of course very, very simple; it is nothing more than a wire with a slight bend in the end and the bend is in contact with the tape. At this point, the small voltage is applied, the aluminum evaporates, literally, and you have a window. This window then is an information kit.

Now, let's just pick a number, say 32 channels of information and 50,000 bits of information per channel. The total recorder and its motor for a month's unattended operation might then occupy a space which was an 8-inch cube, which is quite nice and compact. And I am including in that a power supply, in this case probably a spring motor, to drive this.

The uses that we envision are primarily those in which information must be collected at a wide or large number of unattended or semi-unattended stations, such as the satellite stations mentioned by the previous speaker. In this case the recorder might in some applications sit for a month with no operations taking place except the basic recording on environmental data. At the end of this month someone might come by, let's say, and perform two functions. One, remove a cartridge which would contain the month's information and two, wind up the spring motor. This would not apply in a case where daily interrogation of the stored data were required, although it is quite possible to design a recorder which will record a day's information and then make this stored day's information, or stored hours information available for rapid transmission from the command of a central station. But the basic application still is one in which many recorders are unilaterally feeding information to a central processing station. The reason for this strict nature of the application as we see it, is that although the recorder itself is as you have been able to gather, quite simple, the read back techniques are very similar to those required for a high quality magnetic tape system. In order to achieve speed in read back, you have to have what is equivalent to very good magnetic tape readers, and this implies normally a machine which is not subject to extremes of temperature, which has a fairly closely controlled power supply, which may or may not have to operate in an air conditioned environment, but which is not a field device. And this has, we feel, restricted the areas of use of this system to those in which the previously mentioned characteristics apply.

There is at this time a digitape recorder reproducer system in operation in the field in a particularly unique area, that is storing information for subsequent direction of a computer, and storing it in a very bad environmental situation. This is with the Navy, and they are concerned with being able to direct computers whose function it is to control the operation of fleets. These computers are shipborne, and they are subject to extremely wide variations in temperature, in shock, in power supplies, and also to magnetic fields which can be quite extreme. And what they felt they needed was a system which would be immune basically to these, and yet a permanent storage for the computer direction information. This storage would not only be permanent but would be capable of being developed or used at very high speeds.

In addition we have developed several small event recorders which are used to record discreet events such as the passage of a certain amount of water through a flow meter, or the collection of a certain amount of water in a rain gauge. Where a discreet amount of material is collected or passed, a pulse is created, and this pulse is recorded on a very small event recorder.

Other areas in which the application is being developed but not actually completed at the moment, are in shipping shock recorders, particularly for missile transportation and the missile component transportation, wherein both the manufacturers and the ultimate user are concerned with finding out just what happened to this while it was being moved, how badly was it dropped, and at what time was it dropped so that we can find out where this occurred. The size, compactness and ability to operate without external power of a recorder of this sort have made it very valuable in that area.

I have, I realize, just touched the surface of the subject, partly because we have in our development just touched the surface, and partly because of time here this morning. But we have covered briefly what digitape is. I have tried to give you a rough idea of the areas in which it might be practical to think of using a system of this sort, and I have also tried to point out the areas which we see at the moment as being possible future applications. What I would like primarily to have you leave with is, (one), the name digitape, and (two), some thoughts of your own as to possible applications which you envision which we haven't yet discovered.

AN INFORMATION STORAGE AND RETRIEVAL SYSTEM IN THE FIELD OF WATER QUALITY

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In the past two and one-half days a great deal of information and many more ideas have been presented here at the symposium. How much of this will you use? Five years from now a situation may arise which deals with information you have heard here. You will undoubtedly recall where you heard this topic discussed, and you will go immediately to your copy of the proceedings. You will know exactly where to look for this. You spent two and one-half days deliberating on the information that has been presented.

How much of this will your associates use? Having spent two and one-half days thinking over these topics, you will know exactly where your copy of the proceedings is. You will remember exactly what topics were discussed. But how much of this will your associates recall? Not very much, I imagine. Undoubtedly they will get a copy of the proceedings, and they may read through all of the articles. But will they recall five years from now just where they saw an article on a particular subject? I doubt it. They may recall that they have seen a paper on this; or they may recall reading it or hearing about it. They may recall talking about it with somebody; but they will not remember exactly where they heard it, and they may have a great deal of difficulty finding where this paper is available. If they don't use it, and it is applicable, they won't use it because they don't know where to find it.

Let's briefly consider how you use any information. Our entire learning process is aimed at using information - using knowledge. In fact, one might even say that using available information is knowledge. this gets us into the area of information storage and retrieval. Information storage and retrieval is basically a library operation. The use of such a system is identical to the normal use of a library. How might information be used by you, by a research worker, a professional man, a scholar? This use is identical. You want information on the latest accomplishments and thinking of others engaged in your particular field. Let's say at this point you are confronted with a new problem. It is something you had not considered before. You will want to know what other people have thought, what they have tried, what they have accomplished. You will want to know what the latest theoretical information is. This probably will not give you a solution to your current problem, but at least this will give you the ability to start work at the highest possible level. In fact, you'd also like to know what approaches have been tried and found wanting - how others have attempted to solve a similar problem, even if they ended up unsuccessfully. You will want to know these items because this will eliminate a lot of possible approaches from consideration. It will leave you with what will be undoubtedly much more fruitful expenditure of your time. When information of this type is available in any particular field, we must use it. Ten years from now the work you will be doing will be based upon the results of the work you are doing at present. Even when the next generation of people start considering problems in this area of water quality, their work should also be based on the results of the jobs that you have done. In working in a field where there is a great deal of information, there is much need to transmit information from one person to another, and even from one generation to another. In a field where there is a great deal of information available, books are not enough. Maybe I really should say books are too much, because the problem here is that there is too much information available. One cannot easily find the information directly applicable to the particular subject you are considering. You have heard the story about the scholar who was doing advanced study. He learned more and more about less and less until finally he knew everything about nothing. There is a bit of truth in this. Part of the problem may be over specialization, but part of the problem is all of the learning one has to do. One has to do much searching that is not productive. The new ideas that have been presented at this conference, these ideas that you have been thinking about, should be used where they are applicable. I am sure that you all realize that many of these will become applicable in your own fields in the future. Anyone who is interested in using these can read about them. Today a person working in a field of water quality can read all of the literature which is published in this particular field. I am not sure that you do. Realizing the responsibilities in your normal operating jobs, you may not be able to find the time to read every bit of literature that comes out. Should you? You should definitely know what is available. At present, though you could read everything if you wanted to spend a lot of time at it, you don't. But remember, this won't continue. Our field is growing. Water quality becomes more and more of a problem as we get more and more use of it. Our problem is going to grow faster than our population grows. Even if it grows only as fast, you know this is a very rapid rate.

For a moment let's consider the fields of law or chemistry. Here are fields where one cannot read all of the current information, much less all of the historical information. There is more published daily in these fields than one individual can read. And yet, in the field of law, the lawyer is only interested in what is applicable. He has a staff which helps him find this, or he finds this himself. He searches through the literature until he finds the particular areas of applicability. He then uses these, considering the job he is working on. In a field such as law or chemistry one cannot know everything. One cannot know everything that has been done. One cannot even know everything that is being done today. These fields are too big. Similarly, our field of water quality is growing. In the very near future it will be impossible for one individual to read all of the current literature as it comes out. Right now one can, although it is a strain. At some point in the near future one will not be able to. The growth in this field is evidenced by the ideas presented at our symposium. Concepts are considered here which I am sure many of us never thought of five years ago. This problem, the problem of finding applicable literature, is one which is with us now. The literature available in our field is not so great that we cannot be acquainted generally with all of it; and when confronted with a problem, know where to go to get our answers. This will not continue too far in the future.

Right now if you want articles dealing with, let's say, continuous stream sampling and pollution load and radioactivity and non-chemical evaluation, how will you find it? You want all individual articles dealing with all four of these things. You might be able to put your finger on a particular article just from recalling where you had read it or heard it presented. Would this be true of every one of your colleagues? These are people who have the same problems that you do. Will this be true five years from now? Maybe it will. Will it be true ten years from now? Definitely not. Ten years from now you will be completely unable to follow all of the current literature. Before we consider the automatic storage and retrieval approach to the problem I previously mentioned, let's look at how a librarian would handle it. You would go in to the librarian and say you were interested in articles dealing with continuous stream sampling and pollution load and radioactivity and non-chemical evaluation. You are interested in all of the articles that deal with all four of these things. What would your librarian do? Your librarian would give you all of the articles dealing with each of these individual items. Not articles which dealt with all of them. And even if you have an extremely good librarian who can give you an article or two that deals with all four of these items, this person will not be able to give you all of the articles that deal with all of these four things. Let's take this a step further and say your librarian can give all of the available articles that deal with the combination of these four things. What if you wanted the articles that dealt with a combination of twelve separate things? Would the librarian be able to give you these? I very much doubt it. There might not be many papers that dealt with all twelve of these things, but if there are any, you are really interested in them. Here we come to a point where we can effect a man-machine partnership.

One system for doing this through automatic machine processing would be as follows. Every time a publication comes in to our library, it is entered into the library and given a consecutive number. This article is then abstracted. It can be abstracted by a professional person or a sub-professional with some orientation in the field. The abstract is then filed. Following this, the article is extracted. An individual, and again this can be a professional person or someone with only a technical orientation in this area, goes through the article and writes down each of the descriptive words that would describe the contents of this article. Examples of some of these descriptive words are: continuous stream sampling, pollution load, radioactivity, or non-chemical evaluation. Every one of the descriptive terms would be entered against the consecutive number for this article. On some form of recording of media, possibly punched cards, enter the article number and each of the identifying terms that describe this article. When you would like to query the system you merely ask for articles dealing with specific terms - this, and this and this and this and this and this. One now goes through some mechanical operation and the system will give you a set of numbers. These numbers are the same consecutive numbers which we originally assigned to articles as they came into our library. You take these numbers and now go to the abstracts. You read the abstracts to determine what articles to further study. The obvious advantage of this type of system is that one can handle multiple queries. Everyone of these, had to be included for an article to give you desired information. Utilizing this man-machine partnership it is now possible to ask more realistic questions. Not only do you want articles dealing with this and this and this item. You may now also consider articles dealing with this and this and either this or this. For instance we might be interested in all articles that dealt with continuous stream sampling and pollution load and either radioactivity or non-chemical evaluation. This is a more sophisticated retrievel system, but again our answers are the same.

Information storage and retrieval should really be one word. Retrieval is not enough. We must regularly keep information coming in so that it is available to be retrieved.

The response we can get from a system like this can require minutes, or it may take hours, possibly overnight. I am sure you are aware this will depend on how large a system we have, how many queries normally come to this system, and how important it is to have the information available immediately. What are we talking about costwise? To handle a system of this type we can get along with equipment which would cost anywhere from $1500 a year to half a million dollars a year.

Information storage and retrieval systems are presently being used in many, many places. A great many companies have systems of this type for their internal publications. Bendix and Dupont are examples of this. every time an internal technical publication is made it is entered into their library. I think we can anticipate Dupont Company's need for this type of system to increase beyond what it is today. But I think we can anticipate a far greater increase in the need for this type of system in our area, water quality. Bendix and Dupont are not the only companies doing this, but they are representative.

Initiation of this type of system is often done by professional societies. These people are interested in maintaining information storage and retrieval systems in their areas of application. Western Reserve University has been acting as an agent for the American Society for Metals, setting up, maintaining, and operating an information storage and retrieval system. For those of you who are interested in details of the technical work, a number of good books have come out of the Western Reserve work. Similarly, there is a considerable amount of literature available on a less technical level. In April of this year IBM conducted an information storage and retrieval conference in Poughkeepsie, New York. There were a number of papers presented at this conference dealing with information retrieval systems. Similarly, in October, 1959, at the annual meeting of the Documentation Institute held at Lehigh University in Bethlehem, Penn., a set of papers was presented dealing with information retrieval systems for small information retrieval files. Papers from both of these conferences are available. Some of you may even be acquainted with the system which was developed in the area of air pollution. This is a uniterm system which was developed on the west coast. It is being maintained there today. The area of air pollution is one similar to ours. One could at present keep up with the available information. These people realize that at some point in the future they will not be able to keep up to date. When they can no longer read all of the available information, they want to have a way of getting at it. The need for a storage and retrieval system does not exist in water quality work today. The need is in the future. We can get along without it today and probably do our work almost as well. At some point in the future, maybe five years from now, maybe less, we will suddenly reach a point where we need more information than we have available to us. This information will be available only through a system such as the one we have discussed earlier. If we don't start now we won't have this system available when it is needed. At this time in the futre we may be forced to sit down and start reading the literature, abstracting all of it, extracting all of it, and setting up an information storage file. The cost of doing this, in the future, will be far greater than the cost would be if we did each article as it comes out. Similarly, if we start now, we have the value of a system available to us for all of this period between today and the day when we must have it. Above and beyond this, if articles were abstracted and extracted by their authors at the same time that they were written, this process of abstracting and extracting would be done much better. These people know the work they have done. It is right at their finger tips. Five years from now someone going back through this article may not appreciate many of the aspects of it. The abstracting and extracting will not be as good when it's done in the future. It will cost us more than it would cost us if we did it daily. There is one further benefit of starting a retrieval system immediately. We can start a system now. We will learn about the system as the system grows. We will learn what descriptive terms are the ones we want. We will learn what terms are too inclusive. We will learn these things by using our file. This will make our system much better.

I imagine each one of you sitting out there is thinking, "This really is a good idea. It would be nice to have, but in my particular job it is not my responsibility to see that this is done. In fact, I am not even in a position to consider doing it." I'll be the first to admit this is true. Many of you out there would like to have this. You aren't in a position to do it. You should not be doing it. But don't just shrug off the subject at this point. You would like to have it now. It is something you must have sometime in the future. It's far better to start it now. If you feel that it is not your responsibility, you know someone who you feel should seriously consider this; tell them and see that they do something about it. It is up to you.

SUMMARY OF SYMPOSIUM

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During this past two and a half days we have listened to some thirty-five papers from the pens of forty-one authors. The aim of these papers has been generally toward the subject "Water Quality Measurement and Instrumentation." Some of you might feel that the aim of some of the speakers was in a different direction than you would have taken. Certainly the potshots from the floor toward the speakers were generally well directed. But the main target, rather than the speaker target, was a big one, and although your aim might be different, both you and the speaker may get a piece of that particular target.

Our letter of invitation divided the purpose of this Symposium into three parts: to review in broad terms the methodology, collection and utilization of water quality data; to review available instrumentation and development needs; and to discuss methods of data transmission, distribution, evaluation, storage and other factors concerned with data handling and utilization.

To those Gordon McCallum in his opening added that the Symposium might also define the role of water quality measurement in water resources management.

The time has come now for us to judge the extent we have fulfilled the purpose as outlined. This judgement is one that each of us will make independently, and this brief summary is but one person's attempt to piece together the substantial information that we have been given through these papers that may be used as a basis for making that judgement.

We have been reminded again and again that our future demands for water are likely to exceed the limits of our fresh water supply resources, and that in order to meet this demand it will be necessary to re-use water to a much greater extent than we do at present. This in itself of course will call for much more sharply defined water quality management, and if we are to put such management on a scientific basis, it is obvious that we must have knowledge of the quality of water. This knowledge must be obtained through analyses that are reliable, and in some instances quite refined, and in many instances rapid. Again, we have been reminded that merely to have the data is of no value unless they are used, and of course hopefully that they may be used wisely in the management operation. Toward this end, criteria by which the quality should be evaluated are required. Although considerable data are available that are useful in formulating criteria, there are gaps and limitations, since it is unlikely that we shall ever fully understand the ecological pattern involved in man's relationship to the water environment. But it is encouraging to note a lesser inclination to curse the darkness and more desire to light a candle or two.

Perhaps the biologists are more aware of the complexity of the microcosm that we are concerned with than are some of the rest of us, and as in the past will continue to contribute to an understanding of the relationship of the parameters of water quality that we now know how to measure to the environmental problem.

But the limitations that we may have in understanding the whole structure do not and should not deter us from working piecemeal on the problem. There may be some danger in separating our activity from our contemplation, and I think we have done some of that during this meeting. And several of our speakers have, with respect to their various disciplines, reminded us that common sense is still useful in our sampling, analysis, and data interpretation programs.

I am reminded of Dr. M. Starr Nichols of our State Laboratory of Hygiene who retired a couple of years ago and was rehired and retired again this past year and was rehired and is teaching again. When the young engineer with the State Water Pollution Committee, or the State Health Department, would collect a sample, he would send it into the Laboratory and usually it would say "Run a complete analysis." Dr. Nichols would store the sample and send a note back asking the young engineer to come in and see him, and then he would ask him specifically what he was going to do with each piece of information that he was going to get from the complete analysis. If he had a reasonable answer, he then of course would complete the analysis.

Now the only pertinence of that, of course, was to train the young individual in the necessity for contemplating the reasons why he was having certain work done, and separating that contemplation from the activity of going ahead and getting all the information that he could possibly get.

Now I don't mean to say that if we have all the data, if we have it all stored, if we have it all retrievable that we won't be able to find out things that our common sense would not lead us to. But I think that the common sense approach can still be useful and should not be discarded.

Some of you may feel perhaps that the bacteriological parameters have not received as much attention in this Symposium as their importance warrants. Is this because we are confident that the measurements we now make are perfectly satisfactory? Or is it because we can't see how instrumentation could be readily fitted to a continuous recording system for this particular parameter and so we had better stay on firmer ground in the discussion?

Specifically we have been apprised of certain techniques, of methodology in the collection of water quality data, and to some extent the interpretation of such data. This included such things as radioactive material and dissolved and suspended fractions, activities and measurements of tidal waters and municipal water treatment plants by industry, by consultants, by biologists, and by federal agencies. We have been told that to industry in general every possible parameter is a necessity, but that water quality for each industry is dissimilar, thus making the importance of the parameters widely varying. We have recognized them. And here my more extensive notes run out because of limitations of time, but we have recognized then that there are many parameters which we would like to know more about. But we must ask ourselves whether our inquiry as to the information that we would like to have is really going to be useful to us. We must recognize, also, that while we have spoken glibly about pollution, we really haven't defined pollution because it defies definition. We recognize that pollution is strictly a relative term. It depends upon the particular use the person wants to make of that water. And so what might be polluted to one user is far from being polluted to another. Consequently the parameters in which he might be interested are quite different than the parameters in which another person might be interested.

So it doesn't hurt us to get back to some of the basic definitions and considerations of the pollution problem, or the water quality problem if we are to make intelligent use of the tremendous knowledge that has been given to us in the way of instrumentation and methods of determining various constituents in water supplies.

We see, for example, that the biologist now recognized his need for data in the micro habitat. This has been recognized by the micro meteorologist, a whole clan of which has now developed. In Wisconsin they no longer consider the effect of the temperature and humidity at the weather station on the growth of corn. They are measuring the atmosphere right around each ear of corn. They recognize that this is the environment in which that ear of corn is developing, and consequently that micro habitat is the important area in which the instrumentation is needed to gather the data.

We are still in many of our analyses approaching this from a rather gross problem, but that doesn't mean that we should cease because we don't understand the micro habitat. We recognize, at least the biologists recognize that as far as the fishes and the spawning areas are concerned, it doesn't make much difference what the condition of the water is a few feet away, it is what the condition is in the immediate environment.

Dr. Lackey mentioned, for example, water hyacinth control in Louisiana, annual grass problems and so on. Now these are areas of course in which particular people have particular problems.

But let's get back for a moment to our objectives. Have we reviewed in broad terms the methodology, collection, and utilization of water quality data? I hope to leave a few moments time so that we can discuss some of these things and perhaps get a difference of opinion.

Need we review that in this group? I think that we do. I think that we have. Perhaps not completely, but certainly some of the papers were directed towards information, or gave information about methods and collection with which I was not completely familiar, and I am sure that others would join me in saying that.

I am not so sure that we covered the utilization of the data particularly well. We saw, or at least heard, one speaker who pointed out the necessity for a repository of these data, making them available so that they could be more fully utilized. Again, before we can fully utilize them, we must ask ourselves very critically for what purpose we intend to use those data? What do we wish to find out or define by those data?

The question of second purpose was to review the available instrumentation and development needs. Have we done that? Have the manufacturers laid out for us the available instrumentation? Have we told them what our needs are? Have we done that specifically? Have we given them a well defined goal? We heard one manufacturer point out that the development costs are high for many instruments, and of course they must have some idea of what the market is going to be for those instruments. Have we specifically defined for them what our real needs are? Are we still in some areas like the young engineer who wanted a complete analysis run? Is the information that we are obtaining through our network useful to us? I think it is. I think most of you will agree with me that it is useful to us. Is it so useful that the Public Health Service is willing to buy a recording pH meter for each of the stations? Is that continuous record of information with that kind of instrument which is fully developed, which is available, which is reliable, is that kind of information more useful to them than the kind of information they are now obtaining?

Is it as useful as the expenditure for those instruments would represent? Is the United States Geological Survey ready to buy from the instrument manufacturer the great number of recording meters that have been developed and are reliable? Is each water plant operator willing to do that?

Mr. Baxter pointed out both in his paper and in questions, that he would be willing to buy any instrument which he could justify on the basis of improved performance of his plant or reduced cost in his operations. This, of course, is a very businesslike approach to the problem, and of course, it is the kind of businesslike approach to the problem that the water superintendent must use in his production process.

Leon Smith, who is now dead, and for many years was the Water Superintendent for the City of Madison, operated that utility strictly as a utility, as many of you in water business do. He paid rent to the city and sold water to the city, he ran it completely as an independent utility, but still part of the city.

Certainly in many of our communities, particularly the smaller ones, this sort of justification is very difficult to make. It is difficult to even determine costs for particular areas of operation in many of our water and sewage utilities. Anyone who has made an attempt to break down these cost figures will recognize that difficulty.

On the other hand, have the manufacturers told us what is really wrong with some of the instruments? I don't mean that they are hiding any information from us, but are they willing to say that this instrument is reliable, dependable, and you may proceed to use it for the kind of data that you wish to obtain?

We recognize, of course, that in many instances between the hands of the manufacturer and the use of the instrument, difficulties occur. We can all point to specific examples, but nonetheless we, I think, have a golden opportunity in this kind of conference to be perfectly frank with regard to some of the problems that we face.

I have gathered a great many notes on the papers that have been given. If I devoted a minute to each author, that would take an additional forty-one minutes from this time on. If I devoted a minute to each paper it would take an additional thirty-five minutes. I am sure that isn't what you want me to do.

But let me point out one aspect of this problem that I think that we can devote more attention to, and I sincerely hope that we have a subsequent meeting of this kind.

The sensing instrumentation is an area in which we certainly need a great deal more research. This, of course, has been pointed out by many speakers. For certain analytical procedures, for certain analytical determinations, the sensing operations have been pretty well worked out. We have been told in many instances these have been handed over to us from developments in other industries. We have heard some excellent papers on the transmission of the data, certainly very informative to me and I am sure to many people in the Water Works Industry, and many who are in research activities. This part of the whole picture of gathering data, transmitting and recording certainly is there waiting for us to use it.

The recording of the data, the storage of the data - "this middle section" is pretty well defined, but we are still weak--at least I gather from this meeting--on the sensing and on the response part for the utilization of those data that have been brought to us and stored in the in-between section.

Many of us will have a responsibility to do research in the sensing area, and there is, of course, the political problem involved in the response area. Returning this information for best use is an area in which certain political science as well as engineering is a very important factor.

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